APPENDIX G – TECHNICAL SPECIFICATIONS

S P E C I F I C A T I O N S

NTCRA CLOSURE
ELIZABETH MINE
STRAFFORD, VERMONT

TECHNICAL SPECIFICATIONS

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A. Remove all surface debris, trees, shrubs, and stumps from within the Work Area and other areas as approved or designated by the Engineer.

B. Dispose of cleared shrubs, trees, stumps, cobbles, boulders, and debris as shown on the Drawings in areas designated by the Engineer (Part 3.6).

C. Remove old equipment and building debris, if found, from within the Work Area and dispose of as designated by the Engineer (Part 3.6).

1.3 DEFINITIONS

A. Site Clearing – the removal, hauling, and disposal of surface debris, trees, boulders, and shrubs from within clearing limits shown on the Drawings.

B. Grubbing – the removal, hauling, and disposal of rocks, boulders, stumps, roots and other vegetation below ground, debris, and obstructions from within the clearing limits shown on the Drawings.

C. Stripping – the removal and disposal or re-use of organic soils (topsoil) from within the limits shown on the Drawings.

1.4 RELATED SECTIONS

A. Section 02200 Earthwork

PART 2 – PRODUCTS:

Not Used

PART 3 – EXECUTION:

3.1 PREPARATION

A. Clear and grub within the TP-3 excavation limits and other areas as shown on the Drawings.

B. Limit the area of clearing and grubbing to the minimum area possible that allows for the proper construction of the Work as shown on the Drawings.

C. Install temporary erosion control measures in accordance with the approved Sediment and Erosion Control Plan and as directed by the Engineer.

3.2 PROTECTION

A. Protect benchmarks and survey monuments from damage or displacement. Any benchmarks or survey monuments damaged during clearing and grubbing shall be repaired or replaced immediately.

B. Locate, identify, and protect utilities and existing historic structures from damage.

C. Protect existing trees and other vegetation along the perimeter of the limits of clearing against unnecessary cutting, breaking or skinning of roots, skinning or bruising of bark, smothering of trees by stockpiling within the drip line, excess foot or vehicular traffic, or parking vehicles or equipment within the drip line.

D. Protect existing mine buildings, building relics, and mine infrastructure from damage to the maximum extent practical.

3.3 CLEARING

A. Clear areas required for access to Site and the execution of Work.

B. Remove all trees, shrubs, deadwood, boulders, and other surface debris within the clearing limits. Set aside large trees for the property owner's use with consideration for Site access as directed by the Engineer.

C. Chip and stockpile trees as directed by the Engineer.

3.4 GRUBBING

A. Remove all rocks and boulders, stumps, roots and other vegetation below ground, all debris, and obstructions within the clearing limits.

B. Remove the roots from trees, tree stumps, bushes and shrubs to a minimum depth of one foot below the existing or finished grade, whichever is lower.

C. Remove stumps for trees larger than two inches in diameter.

3.5 STRIPPING

A. Strip excavation limit of cover and other areas of topsoil to a depth of at least 0.5 foot within the excavation limits as showing on the Drawing and other areas as approved by the Engineer.

B. All stripped material underlain by waste rock or tailing, such as topsoil from the slopes on TP-1, shall be disposed of as subgrade fill material beneath the geomembrane on TP-1. Stripped material underlain by tailing or waste rock shall <u>not</u> be used as topsoil as designated on the Drawings.

C. Stockpile excess excavated material not meeting the requirements of 3.5.B, and grade to drain unless otherwise directed by the Engineer.

D. Place, grade, and shape stockpile for proper drainage and place silt fences around stockpile to prevent migration of fines from the stockpile areas.

3.6 DISPOSAL

A. Burning will not be allowed.

B. All brush, trees, stumps, debris, refuse and spoil material shall be disposed of properly by the Contractor, as approved by the Engineer.

END OF SECTION 02100

PART 1 – GENERAL:

1.1 WORK INCLUDES

A. Excavating lead-impacted soil at the upper and lower Copperas Factories and placing in the lead disposal area (TP-2).

B. Excavating waste rock (TP-3).

C. Placing waste rock (TP-1).

D. Preparing TP-3 subgrade.

E. Constructing temporary sediment basin.

F. Final grading of TP-1 and TP-2.

G. Preparing subgrade of TP-1 and TP-2 cover.

H. Placing vegetative support layer.

I. Placing lead contact-barrier layer (Copperas Factories).

J. Placing topsoil.

K. Constructing Copperas Road, Mine Road, and access roads.

L. Placing riprap and stone.

M. Excavating tailing along Copperas Brook.

N. Reconstructing Copperas Brook

1.2 RELATED SECTIONS

A.	Section 02100	Clearing, Grubbing, and Stripping
B.	Section 02561	Cover System Performance Testing
C.	Section 02565	Geosynthetics
D.	Section 02597	Geomembrane
E.	Section 02900	Revegetation

1.3 REFERENCES

A. For products or workmanship specified by association, trades, or Federal standards, comply with requirements of the standard, except when more rigid requirements are specified or are required by applicable codes.

B. The date of the standard/reference is the most recent/updated, in effect as of the date of the Contract Documents except when a date is specified.

C. OSHA Title 29 CFR 1926 - Excavation Safety.

D. AASHTO T96: Resistance to Abrasion of small size coarse aggregate by use of the Los Angeles Machine.

E. ASTM C88: Standard Test Method for Soundness of Aggregates by use of Sodium Sulfate or Magnesium Sulfate.

F. ASTM C127: Standard Test Method for Density, Relative Density (Specific Gravity) and Absorption of Coarse Aggregate.

G. ASTM C136: Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.

H. ASTM D422: Standard Test Method for Particle-Size Analysis of Soils.

I. ASTM D698: Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort.

J. ASTM D2487: Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System).

K. ASTM D2922: Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (shallow depth).

L. ASTM D3017: Standard Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (shallow depth).

M. ASTM D4318: Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soil.

N. ASTM D5268: Standard Specification for Topsoil Used in Landscaping Purposes.

O. Vermont Agency of Transportation 2001 Standard Specifications (www.aot.state.vt.us/conadmin/2001standardspecs.htm).

1.4 REQUIREMENTS

A. Perform all work in compliance with appropriate OSHA Regulations.

B. Perform all work in accordance with an approved Work Plan.

1.5 SUBMITTALS

A. Pre-construction Submittal: If required by the Engineer, submit a construction plan for each earthwork activity in advance of the start of earthwork activity. The plan must be approved by the Engineer prior to any earthwork activities. Prepare a construction plan that may include the following:

1. Proposed material source(s).
2. On-site borrow pit operation plan.
3. Proposed soil processing, placement, compaction, and moisture control equipment, including:
    a. Equipment catalog with weight, dimensions, and operating data.

4. Proposed methods of protection of Work, including temporary dewatering, drainage, irrigating and moisture conditions, and frost protection measures.
5. Proposed excavation, stockpiling, regrading and staging plan describing handling and transport of on-site and off-site materials.
6. Other information requested by the Engineer.

B. Submit a list of equipment proposed for use in hauling, placing, and compacting (where applicable) the materials specified herein if requested by the Engineer.

C. Submit the name and location of off-site borrow sources, if used, and material suppliers for soil materials to be used to construct fills specified herein if requested by the Engineer. Include the type of materials to be obtained. Provide from the same source throughout the work. Change of source requires resubmittal and approval.

D. Provide documentation that an off-site borrow source, if used, complies with applicable Federal, State, and local regulations governing operation (i.e., borrow source operating permit).

E. Submit an affidavit from the source owner for each type of off-site soil borrow material stating that to the best of the source owner's knowledge, the site of the source material was never used as a dump for chemical, toxic, hazardous or radioactive materials and is not now nor ever has been listed as a suspected depository for chemical, toxic, hazardous or radioactive materials by any Federal, State, or other governmental agency, department or bureau. The borrow material obtained from off-site shall be free of chemical contamination.

F. If requested by the Engineer, submit a plan for revised on-site haul road(s) prior to start of the work. The plan must be approved by the Engineer. The on-site haul road shall include at a minimum a plan view and typical section of the revised haul road(s).

G. Submit proposed amendment(s) for the topsoil cover. Provide organic material quantity and source.

1.6 DEFINITIONS

A. Compacted Fill or Common Borrow: On-site or off-site soils compacted to a specified density and at specified moisture content. Material obtained from an approved on-site or off-site borrow source or other approved borrow sources and consisting of a well graded mixture of silt, clay, sand and gravel material free from tailing, waste rock, organic matter or other deleterious material and meeting the requirements of Part 2 of this Section.

B. Fines: Material finer than the U.S. No. 200 sieve (ASTM D422).

C. Gravel: Aggregate consisting of clean, hard gravel, crushed gravel or crushed stone meeting the requirements of Part 2 of this Specification.

D. Lime: Agricultural limestone meeting the requirements of Part 2 of this Specification.

E. Off-site Borrow Sources: Fill materials obtained from an off-site borrow source meeting the requirements of 1.6.A and subject to testing for approval.

F. Optimum water content: The soil moisture content which will result in a maximum dry unit weight when subjected to the compactive effort specified by ASTM D698.

G. Pass: One pass is defined as the requirement of successive trips of a piece of compaction equipment, which by means of sufficient overlap will ensure complete coverage of the entire surface of a layer by the equipment.

H. Percent compaction: Percent compaction is defined as follows:

$$\text{Percent Compaction} = \frac{(K_d)_{IP}}{(K_d)_{max}} \times 100\%$$

where

$(K_d)_{IP}$ = the in-place dry density of a particular soil

$(K_d)_{max}$ = the maximum dry density of that same soil, determined by compaction test according to ASTM D698 procedures.

I. Proof Rolling: Rolling a subgrade surface with equipment having an equivalent ground pressure of a loaded 12-yard tandem axle dump truck for the purpose of detecting soft or loose areas.

J. Riprap: A graded mixture of boulders, cobbles and gravel meeting requirements of Part 2 of this Section.

K. Stone: Aggregate consisting of clean, hard gravel, crushed gravel, or crushed stone meeting the requirements of Part 2 of this Specification.

L. Suitable Fill, Suitable Material or Common Borrow: Material imported to the Site or excavated on-site from an Engineer-approved borrow source that is free from tailing (as applicable), waste rock (as applicable), deleterious substance, and unsuitable materials, which meets the specification requirements for a designated fill.

M. Tailing: Milled waste material from mineral processing consisting of silty sands, sandy silts, and plastic silts and clays.

N. Tracking: Running/tracking a tracked vehicle such as a bulldozer to create tread grooves perpendicular to the slope to roughen slope. Tracking would be used to prepare a soil surface for subsequent soil placement or to prepare a surface for seeding.

O. Topsoil: Salvaged on-site materials, off-site material or manufactured material as specified herein and containing sufficient organic material to promote growth for revegetation (Section 02900).

P. Unsuitable Materials: All soil materials that contain tailing, waste rock, slag, heap-leach material, biodegradable material, timbers, roots, frozen material, stones larger than specified herein, debris, trash, contaminants, and any other objectionable material as determined by the Engineer to be unsuitable for uses as fill. Gap graded or segregated materials shall not be permitted unless approved by the Engineer.

Q. Vegetative Support Soil: Material imported to the Site or excavated on-site from the approved on-site borrow source that is free from tailing, waste rock, deleterious substance, and unsuitable materials, which meets the specification requirements for common borrow.

R. Waste Rock: Commingled, non-milled, processed, waste material from mining, consisting primarily of soils, gravels, cobbles, boulders, ore, cap rock, wood and other waste and debris, and clearing and grubbing waste.

S. Well graded: A grading of material that has no specific concentration or lack thereof, of one or more sizes.

1.7 PROJECT/SITE CONDITIONS

A. Exploratory investigations are not sufficiently complete to disclose all defects that may exist within the TP-3 excavation limits that will be encountered during construction.

B. Final grade lines will be determined by the Engineer in the field based on the conditions encountered, and will vary from those shown on the Drawings.

C. Final grade lines will in all cases be determined by the Engineer.

D. Artifacts from historic mine operations may be encountered during excavation. Engineer shall be notified if, and when, artifacts are encountered. Handling of artifacts shall be at the direction of the Engineer.

E. If human remains are encountered during excavation all work must cease immediately. Notify Engineer immediately for further directions.

PART 2 – PRODUCTS:

2.1 GENERAL

A. Strictly adhere to the local hauling requirements and traffic laws. Act promptly to respond to any complaints or problems related to trucking. The Engineer reserves the right to require the removal of any truck driver or subcontractor from the project who willfully disregards the provisions of this Specification, traffic plans, or traffic laws.

B. Material Quality Testing: Each borrow source and material for soil materials shall be subject to specified testing to determine acceptability. Such testing is intended to result in approval or rejection of a material or source. Conduct testing on proposed borrow sources and materials before importing to the Site and before placement.

2.2 COMPACTED COMMON BORROW/ COMPACTED FILL

A. A well graded mixture of clays, silts, sands and gravels with a maximum particle size of 6 inches unless otherwise directed by the Engineer. Compacted fill shall meet the requirements of suitable fill and have no less than 20 percent fines.

B. Processed material from on-site or an approved off-site borrow source which meets the requirements of paragraph 2.2.A is acceptable as compacted fill.

2.3 RIPRAP

A. A well graded mixture of cobbles, and gravel which are blasted, or crushed rock with a bulk specific gravity (saturated surface dry) equal to or greater than 2.9 as determined in accordance with ASTM C127.

B. A hard, durable, angular, stone of such quality that they will not disintegrate or significantly deteriorate on exposure to freezing and thawing, wetting and drying, and erosion weathering.

C. Riprap shall be well graded mixture of cobbles and gravels.

D. Riprap will generally conform to the gradation guidelines as follows:

1. 7-Inch Minus Riprap

Size*	Minimum Diameter
D_{100}	7 inch
D_{85}	6 inch
D_{50}	4 inch
D_{30}	3 inch
D_{15}	2 inch

*D_x= Diameter which x percent is smaller than by weight.

2. 10-Inch Riprap

Size*	Minimum Diameter
D_{100}	10 inch
D_{85}	6 inch
D_{50}	5 inch
D_{30}	4 inch
D_{15}	3 inch

*D_x= Diameter which x percent is smaller than by weight.

3. Other Riprap gradations, if required, shall be determined by the Engineer.

E. The breadth or thickness of any piece of riprap shall not be less than one-third of its length and meeting the requirements of suitable fill.

F. A maximum sodium sulfate soundness loss of 10 percent when tested in accordance with ASTM C88.

G. A maximum percent of wear (LA Abrasion Test) of 50 percent in accordance with AASHTO T96.

H. Processed materials from an Engineer-approved off-site borrow source which meet the requirements of the Specifications is acceptable as Riprap.

2.4 STONE/GRAVEL

A. 1-inch Stone shall meet the requirements of Vermont Agency for Transportation 2001 Standard Specification 704.12 Aggregate for Surface Course and Shoulders.

B. Gravel Surface shall meet the requirements of Vermont Agency for Transportation 2001 Standard Specification 704.12 Aggregate for Surface Course and Shoulders

C. Gravel Sub-base shall meet the requirements of Vermont Agency for Transportation 2001 Standard Specification 704.04 Gravel for Sub-base.

2.5 COBBLES AND BOULDERS

A. Hard durable rounded to subrounded stone of such quality that they will not disintegrate or significantly deteriorate on exposure to freezing and thawing, wetting and drying and erosion weathering.

B. Waste rock shall not be used for cobbles and boulders.

C. Blasted or crushed rock shall not be used for cobbles and boulders.

2.6 VEGETATIVE SUPPORT SOIL

A. A well graded mixture of clays, silts, sands and gravels generally meeting the gradation of on-site borrow and meeting the requirements of common borrow.

B. The maximum particle size shall be determined by testing using on-site materials and geosynthetics as described in a testing program to be provided by the Engineer.

C. Processed material from on-site or approved off-site borrow source, which meets the requirements of Paragraph 2.5.A is acceptable.

2.7 TOPSOIL

A. Soil which shall be free from tailing and waste rock and reasonably free from brush, objectionable weeds, other litter, clay lumps, roots, clumps of organic matter, rocks greater than 2 inches, and other materials or substances that might be harmful to plant growth or a hindrance to grading, planting, and maintenance operations.

B. Topsoil shall be classified as a SM, ML, SC or CL under the Unified Soil Classification System (ASTM D2487).

C. Topsoil shall contain between five percent to twenty percent organic matter as determined in accordance with ASTM D5268, or as directed by the Engineer.

D. Topsoil shall have a pH between 5.5 and 7.6.

E. Topsoil shall be naturally occurring soil or soil amended by adding organic matter and other materials using a plan approved by the Engineer.

2.8 LIME

A. Lime shall be certified agricultural quality lime, limestone, or other materials approved by the Engineer.

B. Application rates will be as directed by the Engineer.

PART 3 – EXECUTION:

3.1 GENERAL

A. Prior to initiating any work covered by this Section, become thoroughly familiar with all Site features, Site conditions, and all portions of the Work in this Section.

B. Verify that work areas have been properly prepared, stripped and dewatered to remove vegetative matter, roots, objectionable and loose materials, materials that are determined to be objectionable that might interfere with the bonding of fill to foundation, the bonding of fill to fill, and the compacting of materials.

C. Do not perform any earthwork as specified in this Section in any specific work area until all clearing and grubbing is completed in that area.

3.2 EXCAVATION GENERAL

A. Excavation limits may vary from those shown on the Drawings. Final limits will depend on location of tailing, waste rock, and/or fill. Slope and lengths may differ from those shown on the Drawings.

B. Remove soft, wet, or otherwise unsuitable materials from final excavation limits, as determined by the Engineer. Replace unsuitable material with fill and compact as directed by the Engineer.

C. Shape, slope, and support excavations according to the most current requirements of OSHA and the Site Health and Safety plan.

D. Take necessary precautions to preserve material below and beyond excavation lines in a sound condition.

3.3 WASTE ROCK EXCAVATION

A. Excavate waste rock in TP-3 at the locations and to the lines and grades shown on the Drawings.

B. Excavate waste rock in accordance with the approved Waste Management Plan.

C. Excavate ferricrete and altered glacial till (if found) as directed by the Engineer.

3.4 FOUNDATION PREPARATION

A. Do not place materials until the foundation has been suitably prepared and approved by the Engineer.

B. Do not prepare foundation when foundation is frozen.

C. Excavate frozen materials where the foundation subgrade under fill is found to contain frozen areas, as determined by the Engineer and backfill with fill material designated by the Engineer.

D. Excavate soft material where the foundation subgrade under fill is found to contain natural soft areas as determined by the Engineer and backfill with suitable fill material designated by the Engineer.

3.5 SITE GRADING

A. Perform all earthworks to the lines and grades as shown on Drawings, or as directed by the Engineer.

B. Shape, trim, and finish slopes of regraded area to provide free drainage.

C. Neatly blend all new grading into surrounding, existing terrain.

D. Finished site grading shall provide adequate positive surface drainage, as approved by the Engineer.

E. Make grade changes gradual. Blend slopes into level areas.

F. Any eroded or damaged area shall be repaired promptly.

3.6 HAUL ROADS

A. Maintain all haul roads in good condition at all times.

B. Conform to local, county, and state haulage requirements.

C. Construct on-site haul roads as approved in the Contractor’s on-site haul road(s) plan.

3.7 FILL PLACEMENT GENERAL

A. Excavate borrow from within designated areas as directed by Engineer.

B. Do not change elevations or subgrades without a directive from the Engineer.

C. Undercutting of excavation faces is not permitted.

D. Remove soft, wet or otherwise unsuitable materials from foundations, as determined by the Engineer.

E. Shape, slope and support excavations according to the most current requirements of OSHA and the Site Health and Safety plan.

F. Take necessary precautions to preserve material below and beyond excavation lines in a sound condition.

G. Perform required excavations and operations to yield as much suitable material as practical for permanent construction, and preserve for use in permanent construction.

H. Separate suitable materials from materials to be wasted, and minimize handling by placing directly in designated locations.

I. If, in the opinion of the Engineer, the surface of the prepared foundation or the surface of any layer of the fill is too dry and/or too smooth to bond properly with the layer of material to be placed thereon, moisten and/or work surface to provide a satisfactory bonding surface before the next layer of fill material is placed.

J. If, in the opinion of the Engineer, the surface of any layer of the in-place fill is too wet for proper compaction of the fill material layer to be placed thereon, remove and allow the fill to dry or work to reduce the moisture content to the required amount. Recompact before the next layer of fill material is placed.

K. Distribute fill such that it is free from lenses, pockets, streaks, lumps, or layers of material differing substantially in texture, gradation, or moisture content from the surrounding material so as to form as homogeneous a layer of material as practical.

L. Do not place fill when the fill or the foundation on which it would be placed is frozen. Stop fill placement temporarily during unsuitable weather conditions, as directed by the Engineer.

M. Rework materials that have not been placed in accordance with these Specifications. Reworking may include removal, recompacting, reconditioning, or combinations of these procedures, as required by the Engineer.

N. Ensure bonding of new fill to previously placed sloping fill by benching in 2 feet horizontally, as each layer is placed and compacted.

O. Coordinate excavation and placement operations such that fill materials are well mixed and blended to provide homogeneity and compaction.

P. All fill placement shall comply with the approved Waste Management Plan.

3.8 COMPACTED COMMON BORROW/COMPACTED FILL PLACEMENT

A. Moisture/Density Requirements.

1. Compact fill materials in-place to at least 90 percent of the maximum dry density and within minus two (2) to plus three (3) percentage of the optimum water content, in accordance with ASTM D698 unless otherwise shown on the Drawings or as directed by the Engineer.
2. When testing results indicate that the placement, moisture content and percent compaction does not meet the specifications, make adjustments in procedures as necessary to correct the problems and to obtain the specified results.
3. During fill placement, perform in-place density and moisture testing of fill as specified by the Engineer.

B. Place compacted fill in the locations, and to the lines, grades, and thicknesses shown on the Drawings.

C. Place compacted fill in a manner that prevents mixing with other soil materials.

3.9 PREPARING SUBGRADE OF TP-1 AND TP-2 FOR COVER

A. The upper 6 inches (minimum) of the subgrade shall be tailing fill, in situ tailing, or fine sand with a gradation similar to tailing approved by the Engineer.

B. Prepare subgrade to be protective of geomembrane. Subgrade will be graded smooth to allow intimate contact between geomembrane and subgrade surface. Surface shall comply with Specification 02565, Part 3.1.A

C. Survey elevation of subgrade immediately before placing geomembrane to assure elevation meets or exceeds that require by the design. Frequency of survey shall be approved by the Engineer.

3.10 VEGETATIVE SUPPORT AND TOPSOIL PLACEMENT

A. The Contractor shall schedule the work to minimize the time between geomembrane placement and vegetative support soil placement, and between vegetative support layer and topsoil placement.

B. The vegetative support layer shall be placed in a full layer thickness in one operation and in a manner that minimizes stress or potential damage to the cushion geotextile or drainage geocomposite. The vegetative support layer shall be placed from the base of slopes to the top.

C. Only low ground pressure vehicles (track equipment) of 8 psi or less shall travel on the vegetative support layer or topsoil. At no time will construction equipment come into direct contact with the cushion geotextile or drainage geocomposite.

D. Vegetative support soil shall not be end-dumped or stockpiled directly on the geocomposite drain net. Dumping and stockpiling shall only be permitted on previously placed, full-depth vegetative support material.

E. The Contractor shall immediately repair any damage to the cushion geotextile or drainage geocomposite resulting from vegetative support layer placement.

F. The Contractor shall perform the vegetative support soil and topsoil placement in a manner that minimizes material waste.

3.11 RIPRAP, GRAVEL AND STONE PLACEMENT

A. Place riprap, gravel and stone in channels, swales and toe berms to the lines and grades shown on the Drawings.

B. Smooth the riprap by moving rocks in such a manner as to produce a well graded, stable mass of rock with a minimum practical percentage of voids. The finished riprap shall be free from objectionable pockets of unacceptable soil fines, small stones, and clusters of large rocks.

C. Place riprap and stone in a manner that prevents damage to geotextile. Riprap and stone shall be dropped no more than 2 feet on to the geotextile.

D. Place riprap and stone materials to full layer thickness in one operation in such a manner as to minimize segregation and avoid displacement of underlying materials.

E. Do not change finished elevations or subgrades without approval from the Engineer.

F. Riprap, gravel and stone have no moisture or density placement requirements.

3.12 FIELD QUALITY CONTROL

A. The Engineer will take samples and will perform tests for compacted common borrow, vegetative support layer, topsoil, stone, and riprap to evaluate whether the materials meet requirements.

B. The gradation of riprap and stone will be visually estimated in stockpiles and during placement. Additional gradation testing (ASTM D1559, Method C) may be performed by the Engineer prior to placement.

3.13 TOLERANCES

A. All earthworks, with the exception of riprap, shall be finished to within an allowable tolerance of three (3) inches above and zero (0) inches below the grades shown on the Drawings.

B. Riprap and stone shall be finished to within three (3) inches above or zero (0) below the grades shown on the Drawings.

END OF SECTION 02200

PART 1 – GENERAL:

1.1 SECTION INCLUDES

A. Required soil and geosynthetic material, interface and transmissivity testing.

B. Reporting and submittal requirements of test results

1.2 RELATED SECTIONS

A. 02200 – Earthwork

B. 02565 – Geosynthetics

1.3 REFERENCES

A. ASTM D4716: Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head.

B. ASTM D5321 Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method.

1.4 QUALITY ASSURANCE

A. Testing of the transmissivity and shear strength will be performed by a USACE-approved laboratory.

1.5 SUBMITTALS

A. Results of the transmissivity and shear strength testing shall be submitted to the Engineer no later than 30 days prior to installation of any tested material on-site.

PART 2 – PRODUCTS:

2.1 PRODUCTS

A. The Contractor shall use the soil and geosynthetic materials identified in the appropriate Specification sections listed in Part 1.2 of this Section. The Contractor shall clearly identify the material source used for testing. Any change in material source or type between testing and project completion will require Engineer approval and complete retesting at no additional cost.

PART 3 – EXECUTION:

3.1 GENERAL

A. The Contractor shall obtain representative samples of each type of material they proposed for the project in large enough quantities to perform all tests required by the laboratory.

B. The Contractor shall be responsible for shipping the testing materials to the laboratory.

C. Shear resistance testing will be determined for the following interfaces:

1. Vegetative Support Soil/High Transmissivity Drainage Geocomposite. (HT DGC)
2. HT DGC/Geomembrane.
3. Geomembrane/Tailing Subgrade.

D. The Contractor shall obtain approval from the Engineer for the proposed testing laboratory, testing program, materials and procedures prior to implementing testing.

3.2 INTERFACE TESTING

A. Interface testing will be performed by direct shear, in accordance with ASTM D5321 to determine adhesion and angle of friction for each interface and for the Drainage Composite internal strength. Direct shear tests will be performed using a 12-inch by 12-inch shear box. After construction of the test interface, the entire specimen will be soaked in tap water under a normal stress of 50 pounds per square foot (psf) for at least 48 hours. After soaking, each test interface will be consolidated under a specific normal stress of 100, 200, or 400 psf until vertical displacements are stabilized. After consolidation, each specimen will be sheared under its applied normal stress at a displacement rate of 2.0 inches per minute to determine the peak shear and large displacement "residual" strengths. The shear strength shall be determined for both adhesion and friction angle. The total displacement for each specimen will be a minimum of two inches.

B. The interfaces may be tested individually or as a composite of all three interfaces at once. All interfaces shall be tested three times.

C. Using the average lowest peak shear strength and average residual shear (as appropriate) for the three interfaces if tested individually or the average peak shear strength and average residual shear strength for the composite samples, the factor of safety (FS) against veneer failure, as calculated by the methods presented in Attachment A shall be:

1. Static Case using Peak Shear Strength (interface adhesion and interface friction) FS equal to or greater than 1.5.

2. Static Case using only Peak Interface Friction Angle FS equal to or greater than 1.0.
3. Static Case using Residual Shear Strength (interface adhesion and interface friction) FS equal to or greater than 1.1.
4. Seismic Case using Peak Shear Strength (adhesion and friction) FS equal to or greater than 1.5

D. Transmissivity testing will be performed by short-term transmissivity (T_{lab}) in accordance with ASTM D4716 for the for the High Transmissivity Drainage Geocomposite (HT DGC) with the following conditions:

1. Testing configurations include steel plate/Site-specific vegetative support soil/DGC/ geomembrane/steel plate.
2. Applied normal stress is 1000 psf.
3. Hydraulic gradients shall be 0.10, 0.20, and 0.33.
4. Seating period shall be at least 100 hours or until equilibrium is reached, whichever is greater.

E. The minimum hydraulic transmissivity (T_{lab} obtained from ASTM D4716 test with the vegetative support soil) for the geocomposite drainage layer shall be as follows:

1. High Transmissivity Drainage Geocomposite (HT DGC) equal to or greater than 4.8×10^{-4} m^2/sec as tested in accordance with paragraph D above.
2. Low Transmissivity Drainage Geocomposite (LT DGC) equal to or greater than 6.6×10^{-4} m^2/sec based on Manufacturer's published data obtained with a gradient of 0.1 and normal stress of 1000 psf.
3. The above transmissivities are based on design requirements after considering the product of all appropriate long-term reduction factors (1.9) due to creep, geotextile intrusion, chemical degradation of polymeric compound, physical clogging, biological clogging, chemical clogging, scaling effect, and a design FS equal to 4.0.

F. The laboratory shall report all relevant data as outlined in ASTM D5321 and ASTM D4716. The Contractor shall submit the report to the Engineer at least 30 days prior to use of the material on-site.

G. The testing results shall be provided simultaneously to the Contractor and the Engineer.

H. The Engineer may accept or reject the materials submitted for testing based on test results.

3.3 VEGETATIVE SUPPORT LAYER STONE SIZE DETERMINATION

A. The contractor shall provide the required material, equipment and labor to perform the 2 Phase Geomembrane Cushion Testing Program as prepared by the Engineer.

B. The contractor shall work cooperatively with the engineer and others in performing the testing.

END OF SECTION 02561

ATTACHMENT A – Factor of Safety Analysis Method

Factor of Safety Analysis Method

Koerner and Soong (1998) Limit Equilibrium Method

Static Cases

Factor of Safety FS = $(-b + \mathrm{sqrt}(b^2 - 4ac))/(2a)$

Where:

$a = (W_A + N_A \sin\beta) \cos\beta$

$b = -(b_1 + b_2 + b_3)$

$b_1 = (W_A + N_A \sin\beta) \sin\beta \tan\phi$

$b_2 = (N_A \tan\delta + C_a) \sin\beta \cos\beta$

$b_3 = (C + W_P \tan\phi) \sin\beta$

$c = (N_A \tan\delta + C_a) \sin^2\beta \tan\phi$

and

$W_A = \gamma_t h^2 (L/h - 1/\sin\beta - \tan\beta/2)$

$N_A = W_A \cos\beta$

$C_a = c_a(L - h/\sin\beta)$

$W_p = \gamma_t h^2 / \sin 2\beta$

$C = ch / \sin\beta$

Seisimic Case

Factor of Safety FS = $(-b + \mathrm{sqrt}(b^2 - 4ac))/(2a)$

Where:

$a = (C_S W_A + N_A \sin\beta) \cos\beta + C_S W_P \cos\beta$

$b = -(b_1 + b_2 + b_3)$

$b_1 = (C_S W_A + N_A \sin\beta) \sin\beta \tan\phi$

$b_2 = (N_A \tan\delta + C_a) \cos^2\beta$

$b_3 = (C + W_P \tan\phi) \cos\beta$

$c = (N_A \tan\delta + C_a) \cos\beta \sin\beta \tan\phi$

and

$W_A = \gamma_t h^2 (L/h - 1/\sin\beta - \tan\beta/2)$

$N_A = W_A \cos\beta$

$C_a = c_a(L - h/\sin\beta)$

$W_p = \gamma_t h^2 / \sin 2\beta$

$C = ch / \sin\beta$

Input Values for Veneer Stability Case

Variable	Static Case with Peak Strength	Static Case with Peak Friction	Static Case with Residual Strength	Static Case with Peak Strength
C_S = seismic coefficent=	na	na	na	0.10
L = length of geomembrane on slope, feet =	158	158	158	158
H = height of slope, feet =	50	50	50	50
β = slope angle, degrees =	18.4	18.4	18.4	18.4
h = thickness of cover, feet =	2.0	2.0	2.0	2.0
γ_t = total (moist) unit weight of cover soil, pcf =	125	125	125	125
ϕ = friction angle of cover soil,degrees =	35	35	35	35
c = cohesion of cover soil, psf =	0	0	0	0
δ = interface friction angle, degrees =	Lowest Peak	Lowest Peak	Lowest Residual	Lowest Peak
c_a = interface adhesion, psf =	Lowest Peak	0	Lowest Residual	Lowest Peak
Required FS=	1.5	1.0	1.1	1.1

PART 1 – GENERAL:

1.1 SECTION INCLUDES

A. The Work specified in this section includes the installation of geomembrane, drainage geocomposite, geotextiles and pipes.

1.2 RELATED SECTIONS

A.	Section 02200	Earthwork
B.	Section 02561	Cover System Performance Testing
C.	Section 02597	Geomembrane
D.	Section 02712	Drainage Geocomposite

1.3 DEFINITIONS

A. Construction Quality Assurance Officer (CQAO). The Engineer will serve as the CQAO and is responsible for approving the Quality Assurance/ Quality Control Plan and for observing and documenting activities related to quality during construction.

B. Manufacturer – party responsible for manufacturing the geosynthetic.

C. Testing Laboratory – a USACE approved geosynthetic testing laboratory independent from the Manufacturer and Installer responsible for conducting laboratory tests on samples of geosynthetics.

D. Installer – party responsible for the field handling, transportation, storing and deploying the geosynthetics.

1.4 SUBMITTALS

A. The contractor shall provide the Engineer with the following items: a QA/QC Plan based on Manufacturer recommendations, shop drawings and a written description detailing the proposed methods to be employed for performing the Work. All materials and supplies to be incorporated in the Work shall be described, including seaming plans, installation procedures, and quality control programs, and any other information needed to show proposed methods for conforming to the Drawings and Specifications.

B. Documentation of the Manufacturer's qualifications and quality control program.

C. Submit certified test reports that the geosynthetics are manufactured in accordance with the Manufacturer's Quality Control program.

D. Submit documentation of the Installers qualifications and experience as requested by the Engineer.

1.5 QUALITY ASSURANCE TESTING

A. Quality assurance testing and inspection shall be in accordance with Manufacturer's recommendation and industry standards.

B. Obtain samples of each type of geosynthetics delivered and test for conformance to these specifications.

<u>PART 2 – PRODUCTS:</u>

2.1 MANUFACTURE

A. Geosynthetics shall consist of new, virgin material manufactured specifically for this work and will have satisfactorily demonstrated, by prior testing, to be suitable and durable for such purposes.

B. The geotextile shall be a non-woven polypropylene geotextile with the following properties.

1. Weight - 8 ounces per square yard (nominal).
2. Apparent Opening Size - 80 U.S. Sieve (minimum average roll value).
3. Trapezoidal Tear Strength - 80 pounds (minimum average roll value).
4. Puncture Strength - 110 pounds (minimum average roll value).
5. The Engineer shall review other properties of the selected geotextile and approve prior to installation.

C. The cushion geotextile shall be a single layer or multiple layers of a non-woven geotextile with a combined mass of at least 24 ounces per square yard as shown on the Drawings.

D. The drainage geocomposites shall be of a so-called tri-planer construction consisting of a core material with a geotextile bonded to one or both sides. The geotextile shall meet the requirements for the geotextile in Part 2, 2.1.B of this specification. The drainage geocomposite shall have a minimum transmissivity as specified in Specification 02561, Part 3.2.E. The geocomposite shall comply with Specification 02712 or equivalent specification approved by the Engineer.

1. The drainage geocomposite shall have a geotextile bonded to both sides where used on slopes steeper than 6 horizontal to 1 vertical.
2. The drainage geocomposite shall have a geotextile on the upper surface and may have a geotextile on the lower surface where used on slopes equal to or less than 6 horizontal to 1 vertical.

E. The geomembrane shall be linear low density polyethylene (LLDPE) geomembrane. The geomembrane shall have a minimum thickness of 60 mil. The geomembrane shall comply with Specification 02597 or equivalent specification approved by the Engineer.

1. The LLDPE shall be textured on both sides where used on slopes steeper than 6 horizontal to 1 vertical.
2. The LLDPE may be smooth or textured on one or both sides where used on slopes equal to or less than 6 horizontal to 1 vertical.

F. Pipes, culverts, drain tubing fittings and other components shall be high density polyethylene pipe manufactured by Hancor, Inc or equivalent.

1. Pipes, culverts and tubing 24 inches in diameter or smaller shall be equivalent to Hancor AASHTO single wall pipe.
2. Pipe and culvert larger than 24 inches in diameter shall be equivalent to Hancor Sure-Lok® ST pipe.

2.2 WARRANTY

A. Materials shall be warranted against Manufacturer's defects for a period of 5 years from the date of completed installation.

B. Installation shall be warranted against defects in workmanship for a period of 1 year from the date of completed installation.

PART 3 – EXECUTION:

3.1 SUBGRADE

A. The geomembrane subgrade shall be prepared in accordance to Manufacturer's recommendation and those specifications for foundation preparations.

B. All subgrade damaged by construction equipment and deemed unsuitable shall be repaired prior to placement of the geosynthetic at the Contractor's expense. All repairs shall be approved by the Engineer.

C. The subgrade shall be accepted by the installer by a written certification.

3.2 FIELD INSTALLATION

A. Field installation will be in accordance with the Engineer approved plans and follow Manufacturer's recommendations.

B. Field installation shall be in a manner that assures efficiency of material, minimization of seams and proper placement of seams.

C. No equipment, tools or personnel that can readily cause damage to geosynthetics shall be allowed on the geosynthetic during and after installation.

D. Contractor shall provide adequate temporary loading that will not damage the geosynthetic as needed to prevent uplift by wind.

E. If a phased approach is to be employed the Contractor shall incorporate a plan with the Engineer's approval to protect the leading edge(s) of the geosynthetic appropriately to protect it from damage and provide for a clean tie-in to future installation.

3.3 JOINING

A. Join geosynthetics in accordance with Engineer approved plans and following Manufacturer's recommendations.

3.4 TESTING

A. The Engineer shall stipulate the experience required by the geomembrane manufacturer and installer as required in the appropriate specification.

B. Construction Quality Assurance: The Contractor shall prepare a Construction Quality Assurance Plan (CQAP). The CQAP shall address the means and methods to be employed for the installation of geosynthetics. The CQAP shall outline all required tests, testing frequency, observations and documentation of results.

C. Manufacturing Testing: The geosynthetic Manufacturer shall supply certified test reports in accordance with Part 1.5.C of these Specifications.

D. Field Testing: Field Testing shall be conducted by the means and methods presented in the CQAP. Field testing shall be conducted in a manner and method that minimizes the need for repairs or rework.

END OF SECTION 02565

PART 1 – GENERAL:

1.1 SECTION INCLUDES

A. The Work specified in this section includes the installation of a 60 mil linear low density polyethylene (LLDPE) geomembrane liner.

1.2 REFERENCES

A. ASTM (American Society for Testing and Materials)

1. ASTM D5199 Standard Test Method for Measuring the Nominal Thickness of Geosynthetics.
2. ASTM D5994 Standard Test Method for Measuring Core Thickness of Textured Geomembrane.
3. ASTM D1505 Standard Test Method for Density of Plastics by the Density-Gradient Technique.
4. ASTM D792 Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
5. ASTM D638 Standard Test Method for Tensile Properties of Plastics.
6. ASTM D1004 Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting.
7. ASTM D3895 Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry.
8. ASTM D5721 Standard Practice for Air-Oven Aging of Polyolefin Geomembranes.
9. ASTM D5397 Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test.
10. ASTM D4833 Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
11. ASTM D1603 Standard Test Method for Carbon Black In Olefin Plastics.
12. ASTM D5596 Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics.
13. ASTM D5323 Standard Practice for Determination of 2% Secant Modulus for Polyethylene Geomembranes.
14. ASTM D5617 Standard Test Method for Multi-Axial Tension Test for Geosynthetics.

15. ASTM D570 Standard Test Method for Water Absorption of Plastics.

16. ASTM D746 Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact..

17. ASTM D1203 Standard Test Method for Volatile Loss from Plastics Using Activated Carbon Methods.

18. ASTM D1204 Standard Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature.

19. ASTM D1238 Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.

20. ASTM D1693 Standard Test Method for Environmental Stress Cracking of Ethylene Plastics.

21. ASTM D1898 Standard Recommended Practice for Sampling of Plastics.

22. ASTM E96 Standard Test Methods for Water Vapor Transmission of Materials.

23. FTM 101 Puncture Resistance and Elongation Test (1/8 inch Radius Probe Method), Federal Test method 2065

24. GRI Test Method GM14 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes

25. ASTM D4437 Standard Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes

26. ASTM D6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced using Thermo-Fusion Methods.

27. ASTM D6693 Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polyproplene Geomembranes.

28. ASTM D6747 Standard Guide for Selection of Techniques for Electrical Detection of potential Leak Paths in Geomembranes.

29. ASTM D5321 Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method

30. ASTM D5820 Pressurized Air Channel Evaluation of Dual Seamed Geomembranes.

31. Where reference is made to one of the above standards, the revision in effect at the time of the work shall apply.

1.3 RELATED SECTIONS

A. 02200 Earthwork

B. 02561 Cover System Performance Testing

C. 02565 Geosynthetics

D. 02712 Drainage Geocomposite

1.4 DEFINITION

A. Construction Quality Assurance Officer (CQAO). The Engineer will serve as the CQAO and is responsible for approving the Quality Assurance/ Quality Control Plan and for observing and documenting activities related to quality during construction.

B. Manufacturer – party responsible for manufacturing the Geomembrane.

C. Testing Laboratory – a USACE approved geosynthetic testing laboratory independent from the Manufacturer and Installer responsible for conducting laboratory tests on samples of geomembrane.

D. Installer – party responsible for the field handling, transportation, storing and deploying the geomembrane.

E. Linear Low Density Polyethylene (LLDPE) – An ethylene/α-olefin copolymer having a linear molecular structure. The comonomers used to produce the resin can include hexane, octane, or methyl pentene. LLDPE resins have a natural density in the range of 0.915 to 0.926 g/ml.

F. Formulation – The mixture of a unique combination of ingredients identified by type, properties, and quantity. For LLDPE geomembranes, a formulation is defined as the exact percentages and types of resin(s), additives, and carbon black.

1.5 SUBMITTALS

A. Contractor shall submit the following items to the Engineer:

1. Manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results,

shall be furnished at the time of shipment. The Engineer shall review and approve of the geomembrane prior to installation.

2. Report of test results per Section 02561.

3. Contractors QA/QC manual for geomembrane installation.

4. Geomembrane material, panel installation diagram.

5. Manufacturer's certification of materials.

6. Daily Inspection and testing reports.

7. As-built drawings.

1.6 QUALITY ASSURANCE TESTING

A. Quality assurance testing and inspection shall be in accordance with the manufacturer's recommendations and these Specifications.

B. Contractor shall obtain samples from each lot of each type of geomembrane delivered and test for conformance to these Specifications.

C. Contractor shall perform or have performed the testing outlined in Section 02561 and report the results to the Engineer.

PART 2 – PRODUCTS:

2.1 MATERIAL

A. The LLDPE geomembrane sheets shall be manufactured from pure virgin resin. The pure virgin resin shall be mixed with two to three percent carbon black. No reclaimed polymer shall be added to the resin. Polymer recycled during the manufacturing process may be permitted if done with an appropriate cleanliness and if the recycle polymer does not exceed 2 percent by weight. The carbon black is to be preblended according to specifications of the Geomembrane Manufacturer. The resin shall have a melt flow index value of less than 1.0 g/10 min per ASTM D1238 and a density of 0.926 g/ml or lower.

B. The LLDPE geomembrane shall have a formulated sheet density of 0.939 g/ml or lower. Density can be measured by ASTM D1505 or ASTM D792. If the latter, Method B is recommended.

2.2 MANUFACTURING

A. The sheet material shall be capable of being bonded to itself by thermal bonding in accordance with the sheet manufacturer's recommendations and instructions and seaming requirements of this section.

B. Extruded sheets shall be at least 10 feet in width. Each roll shall be identified by a number and date of manufacture. Paint or markers used for identification shall be of a type which will not degrade the material.

C. The delivered geomembrane sheets shall conform to the following minimum properties.

1. Smooth geomembrane shall conform to Table 1 values.

2. Textured geomembrane shall conform to Table 2 values.

D. The values listed in the tables are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

E. The various properties of the LLDPE geomembrane shall be tested at the minimum frequencies shown in Tables 1 and 2. If the specific manufacturer's quality control guide is more stringent, it must be followed in like manner.

F. Workmanship and Appearance

1. Smooth geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties and hydraulic integrity of the geomembrane.

2. Textured geomembrane shall generally have uniform texturing appearance. It shall be free from such defects that would affect the specified properties and hydraulic integrity of the geomembrane.

3. General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

G. Manufacturer's Quality Control (MQC) Sampling

1. Sampling shall be in accordance with the specific test methods listed in Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

2. The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.

3. The average of the test results should be calculated per the particular standard cited and compared to the minimum values listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave."

H. MQC Retest and Rejection

1. If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

I. Packaging and Marking

1. The geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

2. Marking of the geomembrane rolls shall be done in accordance with the manufacturer's accepted procedure as set forth in their quality manual.

Table 1. Linear Low Density Polyethylene (LLDPE) Geomembrane (SMOOTH)

Properties	**Test Method**	**Test Value (60 mils)**	**Testing Frequency (minimum)**
Thickness – mils (min. ave.) • Lowest individual of 10 values	D5199	nom. -10%	per roll
Density g/ml (max.)	D1505/D792	0.939	200,000 lb
Tensile properties *(1)* (min. ave.) • Break strength (lb/in) • Break elongation - %	D6693 Type IV	 228 800	20,000 lb
2% Modulus – lb/in. (max.)	D5323	3600	per formulation
Tear Resistance – lb (min. ave.)	D1004	33	45,000 lb
Puncture Resistance – lb (min. ave.)	D4833	84	45,000 lb
Axi-Symmetric Break Resistance Strain - % (min)	D5617	30	per formulation
Carbon Black Content - %	D1603 *(2)*	2.0-3.0	45,000 lb
Carbon Black Dispersion	D5596	note *(3)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(4)* (a) Standard OIT **-or-** (b) High Pressure OIT	 D3895 D5885	 100 400	200,000 lb
Oven Aging at 85 ^{o}C *(5)* (a) Standard OIT (min. ave.) - % retained after 90 days **-or-** (b) High Pressure OIT (min. ave.) - % retained after 90 days	D5721 D3895 D5885	 35 60	per formulation
UV Resistance *(6)* (a) Standard OIT (min. ave) **-or-** (b) High Pressure OIT (min. ave.) - % retained after 1600 hours *(8)*	 D3895 D5885	 N.R. *(7)* 35	per formulation

Notes

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- Break elongation is calculated using a gage length of 2.0 at 2.0 in./min.

(2) Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.

(3) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 9 in Categories 1 or 2 and 1 in Category 3

(4) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(5) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(6) The condition of the test should be 20 hr. UV cycle at 75^{o}C followed by 4 hr. condensation at 60^{o}C

(7) Not recommended since the high temperature of the Std-OIT test produces and unrealistic result for some of the antioxidants in the UV exposed samples.

(8) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Table 2. Linear Low Density Polyethylene (LLDPE) Geomembrane (TEXTURED)

Properties	Test Method	Test Value (60 mils)	Testing Frequency (minimum)
Thickness – mils (min. ave.) • Lowest individual for 8 out of 10 values • Lowest individual for any of the 10 values	D5994	nom. (-5%) -10% -15%	Per roll
Asperity Height mils (min. ave.) *(1)*	GM 12	10	Every 2nd roll *(2)*
Density g/ml (max.)	D1505/D792	0.939	200,000 lb
Tensile properties *(3)* (min. ave.) • Break strength -- lb/in • Break elongation - %	D6693 Type IV	 90 250	20,000 lb
2% Modulus – lb/in. (max.)	D5323	3600	per formulation
Tear Resistance – lb (min. ave.)	D1004	33	45,000 lb
Puncture Resistance – lb (min. ave.)	D4833	66	45,000 lb
Axi-Symmetric Break Resistance Strain - % (min)	D5617	30	per formulation
Carbon Black Content - %	D1603 *(4)*	2.0-3.0	45,000 lb
Carbon Black Dispersion	D5596	note *(5)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(6)* (c) Standard OIT **-or-** (d) High Pressure OIT	 D3895 D5885	 100 400	200,000 lb
Oven Aging at 85 ^{o}C *(7)* (c) Standard OIT (min. ave.) - % retained after 90 days **-or-** (d) High Pressure OIT (min. ave.) - % retained after 90 days	D5721 D3895 D5885	 35 60	per formulation
UV Resistance *(8)* (c) Standard OIT (min. ave) **-or-** (d) High Pressure OIT (min. ave.) - % retained after 1600 hours *(10)*	 D3895 D5885	 N.R. *(9)* 35	per formulation

Notes

(1) Of 10 readings; 8 out of 10 must be ≥ 7 mils, and lowest individual reading must be ≥5 mils; also see Note 9.

(2) Alternate the measurement side for double sided textured sheet.

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.

- Break elongation is calculated using a gage lenth of 2.0 in. at 2.0 in./min.

(4) Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:

- 9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hr. UV cycle at 75^{o}C followed by 4 hr. condensation at 60^{o}C

(9) Not recommended since the high temperature of the Std-OIT test produces and unrealistic result for some of the antioxidants in the UV exposed samples.

(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.

PART 3 -- EXECUTION:

3.1 FIELD INSTALLATION

A. Panel Placement: Based on the approved geomembrane panel installation diagrams and material certifications, the individual sheets will be numbered and seams will be identified by using the numbers of the sheets, which create the seam. The proposed layout of panels shall be set and approved, assuring efficiency of material, minimization of welds and proper placement of welds. Any variation from the panel diagram must be approved by the Engineer. Should a variance be obtained, the Contractor shall modify the panel diagram to show the "As-Built" configuration. The prime considerations in seaming shall be to minimize the number of seams made. All overlaps for field seams shall be shingled in a downslope direction.

B. Subgrade: No geomembrane shall be placed over unsuitable or unapproved subgrade. The Installer shall furnish a subgrade acceptance form prior to the installation of each panel indicating acceptance of the subgrade. The following conditions shall be minimum for the subgrade:

1. The subgrade soil shall be as specified in Section 02200 and Section 2565, Part 3.9.

2. No stones or sharp objects shall be present on the area to be lined.

3. The subgrade surface should not be pebbly or tracked and rutted by equipment and shall be free from pockets, holes, and discontinuities which

will cause bridging which would, in the judgment of the Engineer, overstress the geomembrane.

4. Surface moisture shall not be excessively wet or dry or in any condition which will impede proper installation. Under no condition shall the geomembrane be placed over standing water on the subgrade.

C. Water and Wind: The Contractor shall use whatever methods deemed necessary to prevent water or wind from getting under the partially installed geomembrane. Should excessive moisture become trapped below the membrane or if wind damage has been incurred, the Contractor will be required to perform all work, including removing and replacing as much of the in-place geomembrane as the Engineer directs, to assure that the integrity of the geomembrane and the underlying subgrade has not been compromised.

D. Placement: Placement of the geomembrane shall be done such that good fit (thermal expansion or contraction shall be considered), without bridging or excessive contraction, is provided in all corners and grade changes. Excessive slack shall be avoided to minimize rippling. The liner sheets shall be unrolled, deployed and backfilled in a manner which minimizes wrinkles and prevents the occurrence of folds and creases. The wrinkle height to width ratio for installed geomembrane shall not exceed 0.5. In addition, geomembrane wrinkles shall not exceed 6 inches in height. Wrinkles that do not meet these criteria shall be cut out and repaired in accordance with the Installer's QC manual and these Specifications. Liner deployment shall not be performed when precipitation is occurring, when excessive moisture or wet conditions exist, when ambient temperatures are below 32^0F or above 104^0F, or when high winds or other adverse climatic conditions exist, unless approved by Engineer.

E. Liner Protection: No equipment, tools or personnel that can readily cause damage to the liner shall be allowed on the liner during and after installation. Personnel working on the liner shall not smoke, wear potentially damaging shoes, dispose of trash or other debris, or engage in any activity that could damage the liner.

F. Temporary Ballast Loading: Adequate loading that will not damage the liner shall be placed by the Contractor over the liner during installation as needed to prevent uplift by wind and by rapid changes in barometric pressure. This temporary ballast loading shall be in addition to the anchor trenches as shown on the Drawings. Sufficient temporary ballast loading shall be placed along panel edges, in particular, as needed to minimize the risk of wind flow under the panels. Temporary ballast loading may consist of sand filled bags. Bags used for containing sand shall be resistant to degradation by ultraviolet rays.

G. Anchor Trenches: The liner shall be anchored in anchor trenches at the locations shown on the Drawings. Liner anchor trenches shall be no less than 18 inches in width and 24 inches in depth, and the corners of the trenches shall be slightly rounded to minimize sharp bends in the liner. After placement of the liner along one side and across the bottom of the trench, the trench shall be backfilled with compacted vegetative support soil.

H. Repairs: All liner defects (scratches, blisters, rips, punctures, tears, holes, pinholes creases, folds, etc.) and holes created by removal of samples or coupons for destructive testing shall be marked and repaired by completely covering the defect or hole with an oval-shaped piece of the corresponding geomembrane material, that extends out 6 inches from the repair and continuously welding the patch to the liner or sheet using an extrusion weld. Liner repairs shall be documented including date, liner panel number, repair location, type of defect, description of repairs made and results of testing.

I. As-Built Panel Diagram: The Contractor shall prepare the "As-Built" panel diagram locating and identifying seams, individual rolls and panels as they have been placed. The Contractor shall also indicate in that diagram the date on which each seam was performed, the patches and repairs, and the dates each were performed.

3. 2 SEAMING METHODS

A Geomembrane field seaming shall be performed in accordance with the following:

1. All liner shall be ballasted immediately after deployment to prevent uplift by winds. Welding of field seams shall not take place except during suitable ambient weather conditions, as confirmed by field trial test welds.

2. All liner sheets must be continuously and tightly bonded using continuous extrusion fillet welds or double wedge fusion welds and automated welding equipment approved by the Engineer. Field seaming shall be conducted in the dry, on a compacted smooth surface, and in such a manner to prevent dust, dirt, or other foreign material from being included in the seam

3. Adjoining liner sheets shall be overlapped a minimum of 4 inches by adequately lapping the edges of the sheets. The overlap shall not exceed 6 inches for double-wedge fusion welds. The edges to be welded shall be wiped and cleaned thoroughly to remove any dirt, dust, moisture or other foreign materials. All field seams must be uniform in appearance, width and properties, and shall not exhibit warping due to overheating from welding. The peel and shear strengths of the welded seams must comply with the strength criteria provided by the Manufacturer. “T” seams should be patched in accordance to 3.1.H of this Specification.

3.3 TESTING

A. Materials

1. Resin - Factory sampling and testing of raw materials shall be in conformance with ASTM D1898. Factory test reports for the resin shall include the proportions of resin, carbon black and other additives, and test results for melt index, specific gravity, environmental stress crack resistance, low temperature brittleness and oxidative induction time. These reports shall be submitted for approval by the Engineer before installation of any liner material. The following tests and minimum frequency of testing shall be undertaken by the Liner Manufacturer. The resin density and melt index shall be reported for both the unblended resin and the blended resin after adding carbon black and antioxidants. The oxidative induction time shall be reported for the blended resin.

2.

Resin Property	**Method**	**Minimum Frequency**
Density	ASTM D 792	Once per Batch of Resin
Melt Index	ASTM D 1238, Condition E	Once per Batch of Resin
Oxidative Induction Time	ASTM D 3895	Once per Batch of Resin

3. Factory Liner Testing - Factory test reports for each roll of liner shall include test results for the following properties: tensile strength and elongation at yield and at break; tear resistance; puncture resistance; minimum and average thickness; density; carbon black content; and carbon black dispersion. These reports shall be submitted for approval by the Engineer before installation of the liner. Failure of any of the tests shall result in rejection of the corresponding liner rolls. Tensile tests (ASTM D 638) and tear resistance tests (ASTM D 1004) shall be performed in both the machine and transverse directions. Certification of the liner modulus of elasticity, dimensional stability, volatile loss, water absorption and water vapor transmission shall be provided by the liner manufacturer in writing. In support of the certification, the Liner Manufacturer shall submit at least one test result for each property performed within one year prior to the date of the certification on liner manufactured with each type resin supplied to the project.

4. Contractor Liner Quality Assurance Testing – The Contractor shall obtain and secure samples (coupons) of the liner from each lot of material delivered and test for conformance with the properties of this specification. Failure of any sample to meet or exceed the requirements specified herein shall be considered cause for rejection of the material or installed liner section from which the sample was collected to the extent designated by the Engineer. If the Contractor or Liner Manufacturer can establish to the Engineer, via additional test results, that the failed sample is representative of a smaller section of the liner, then only that portion will be rejected.

B. Field Seams

1. Daily Qualifying Welds - At the beginning of each working day, after any interruption in power, after any prolonged idle period during the day, and at the request of the Engineer at any other time during the day, each seamer/welder shall prepare a 3-foot (for extrusion welds) to 10-foot (for double-wedge fusion welds) long test strip using the welding apparatus assigned to him. Five samples from the test strip shall be cut at locations selected by the Engineer and tested by the Contractor in both shear and peel for compliance with these specifications in the presence of the Engineer. The sample weld shall successfully pass the test requirements before either the welder or welding apparatus are allowed to operate on production welds.

2. Non-Destructive Testing of Welds - The Contractor shall continuously test every field weld (i.e., 100 percent of the length of all field seams), including field welds around patches, using non-destructive testing techniques. These tests shall be performed in the presence of the Engineer. Extrusion welds shall be tested using a vacuum box and test procedures specified in ASTM D 4437. Once the soap solution is uniformly placed over the weld and suction applied to the seam, any bubble formation must be noted and the corresponding defective area identified, marked, and subsequently repaired.

   a) Double-wedge fusion welds with a continuous air gap between the two welds, shall be non-destructively tested by pressurizing the gap between the two welds to a pressure between 25 and 30 lb/in^2 and monitoring the pressure for any decline with time, in accordance with ASTM D 5820. After allowing 2 minutes for relaxation, the pressure shall be monitored over a test period of not less than 5 minutes. A weld will be considered satisfactory if either of the following criteria are satisfied:

      (i) the loss in pressure is equal to or less than 2 lb/in^2 and the pressure stabilizes within the 5-minute test period; or

(ii) if criteria (i) is not satisfied, the additional pressure drop is equal to or less than 1 lb/in^2 during an additional test period of 5 minutes (i.e., the total pressure drop is less than or equal to 3 lb/in^2 over a 10-minute test period), and the pressure stabilizes during the second test period.

b) The length of welded section tested by air pressure shall not exceed 450 feet, without prior approval by the Engineer. If a non-compliant pressure drop is noted, pressure testing may be repeated in a step fashion each time halving the length of weld being tested until the extent of the defective weld is determined. Vacuum box testing (ASTM D 4437) may also be used to locate a defect in the top weld or in the top of the air channel.

c) Once the defect is found, it shall be clearly identified, marked and repaired. Any defective seams shall be repaired so that it meets or exceeds the minimum requirements specified herein.

3. Sampling and Destructive Testing –

a) Testing - - The Contractor shall obtain and secure samples of the liner and field seams for destructive testing at locations designated by the Engineer. Samples shall be obtained at a frequency as determined by the methodology of GRI GM 14 "Selected Variable Intervals for Taking Geomembrane Destructive Seam Samples using the Method of Attributes" (Attachment A). The following shall be assumed in developing the GRI GM 14 methodology:

1. Total seam length shall be the total length estimated for each construction season.
2. The anticipated failure percentage shall be 2% unless otherwise authorized by the Engineer.
3. The initial seam sampling frequency shall be 1 sample every 750 feet.

b) The Contractor shall obtain seam samples, in triplicate, from the designated location for field and laboratory testing. One portion of the sample shall be retained by the Contractor for field testing. If the results of field tests performed by the Contractor, in the presence of the Engineer, indicate compliance with these specifications then the Contractor shall send the second portion of the sample to an independent laboratory for testing paid for by the Contractor, and the third portion will be retained by the Engineer's designated representative for archive storage. If the results of peel and shear tests performed by the Contractor in the field do not meet or exceed the requirements specified herein, the Contractor shall apply for temporarily determining the extent of repairs pending performance of independent quality control tests by the Engineer.

The portions of seam samples provided for independent laboratory destructive testing, and provided to the Engineer's designated representative for archive storage, shall each be not less than 12 inches wide by 18 inches long in the direction of the seam. The seam shall be centered along the sample length. Each of the triplicate sample portions shall be properly marked and identified by the Contractor. The Contractor shall repair all holes created by sampling in accordance with these Specifications in Repairs.

c) Seam Strength Criteria - All welded field seams shall meet the following criteria:

(i) When the weld is tested in shear in accordance with ASTM D 6392, the specimen shall exhibit a film tear bond failure (FTB), and the strength shall be equal to or greater than 90 lb/in (ppi). The tests shall be performed at 20 in/min (ipm) until rupture.

(ii) When the weld is tested in peel in accordance with ASTM D 6392, the specimen shall exhibit an FTB and/or the liner must fail before the weld, and the strength shall be equal to or greater than 90 lb/in (ppi). The peel strength criteria shall apply to both the top and bottom welds of double wedge fusion welds. The tests shall be performed at 20 ipm until rupture.

d) Pass/Fail Criteria - The following pass/fail criteria shall be used to determine compliance of field seams with the above strength criteria:

(iii) All five seam specimens from a given sample or coupon tested in peel (both top and bottom for double wedge fusion welds) and all five specimens tested in shear shall exhibit the required strengths, and display FTB failures (i.e., 0 percent strength failures and 0 percent non-FTB failures); or

(iv) All five seam specimens from a given sample or coupon tested in peel and all five specimens tested in shear shall exhibit the required strengths and at least four out of five test specimens, for each type of test, shall exhibit a FTB failure (i.e., 0 percent strength failures and up to 10 percent non-FTB failures); or

(v) If a field seam fails the criteria specified herein, and the Contractor wishes to establish to the Engineer that the failed sample represents a smaller section of the field seam than designated by the Engineer, additional coupons may be obtained at progressively increasing distances from both sides of the failed sample, at locations approved by the Engineer, until two consecutive samples on each side of the original sample pass the field seam criteria. At that point, the extent of the original defect in both directions along the field seam will be considered isolated and the Contractor will then cap/patch, re-weld and re-test the entire length of sampling.

4. Quality Assurance Forms - The Contractor shall adopt and use quality assurance forms approved by the Engineer during all applicable phases of liner installation, inspection and testing. The forms must be submitted to the Engineer at least two weeks prior to liner installation for review and approval.

5. Certification - The Contractor's installation supervisor shall observe and check all phases of the liner installation. When the liner is finally accepted, the Contractor shall submit written certification that the installation conforms to the requirements of the Liner Manufacturer.

END OF SECTION 02597

ATTACHMENT A

Selected Variable Intervals for Taking Geomembrane Destructive Seam Samples using the Method of Attributes

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Adopted March 27, 1998

GRI GM14*

Standard Guide for

"Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes"

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This guide is focused on selecting the spacing interval for taking destructive seam samples of field deployed geomembranes as a particular job progresses based on an installers ongoing record of pass - or - fail testing.

Note 1 - While subjective at this time, the guide is most applicable to large geomembrane seaming projects which require more than 100 destructive seam samples based upon the typical sampling strategy of 1 destructive sample per 150 m (500 ft).

1.2 This guide is essentially applicable to production seams. Caution should be exercised in using the guide for projects that involve complex geometries, multiple penetrations, or extreme weather conditions.

1.3 The primary target audiences for this guide are construction quality assurance (CQA) organizations, construction quality control (CQC) organizations, facility owner/operators and agency regulators having permitting authority.

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

1.4 The outcome of using the guide rewards good seaming performance resulting from a record of passing destructive seam tests. It also penalizes poor seaming performance resulting from a record of excessively failing seam tests.

1.5 This guide does not address the actual seam testing procedures that are used for acceptance or failure of the geomembrane seam test specimens themselves. Depending on the type of geomembrane being deployed one should use ASTM D4437, D3083, D751 and D413 for testing details in this regard. The project-specific CQA plan should define the particular criteria used in acceptance or failure.

1.6 An appendix is offered using control charts which is intended to be of assistance to geomembrane installers, i.e., construction quality control (CQC) organizations, to identify salient aspects of good and poor seaming performance.

2. Referenced Documents

2.1 ASTM Standards:

D4437 Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes

D3083 Specification for Flexible Poly (Vinyl Chloride) Plastic Sheeting for Pond, Canal, and Reservoir Lining

D751 Method of Testing Coated Fabrics

D413 Test Methods for Rubber Property - Adhesion to Flexible Substrate

2.2 Other Standards

ANSI/ASQC Z1.4 [1993]

Sampling Procedures and Tables for Inspection by Attributes

3. Summary of Guide

3.1 Use of this guide requires the establishment of an anticipated geomembrane seam failure percentage (ranging from 1 to 8%) and an initial, or start-up, sampling interval.

Note 2 - The value of anticipated failure percentage is an important consideration. It dictates each decision as to a possible increase or decrease in interval spacing from the preceding value. The percentage itself comes from historical data of the construction quality assurance (CQA) organization or regulatory agency. It is related to a number of factors including criticality of installation, type of geomembrane, type of seaming method and local ambient conditions.

The actual value is admittedly subjective and should be made known in advance to the geomembrane installer before bidding the project. Use of an unrealistically low value of anticipated failure percentage, e.g., < 1.0%, will likely result in field difficulties insofar as decreased sampling intervals are concerned. Conversely, use of an unrealistically high value of anticipated failure percentage, e.g., > 8.0%, will likely result in very large sampling intervals and quite possibly sacrifice the overall quality of the seaming effort.

3.2 The guide then gives the procedure for establishing the initial number of samples needed for a possible modification to the start-up sampling interval. This is called the initial batch. Based upon the number of failed samples in the initial batch, the spacing is either increased (for good seaming), kept the same, or decreased (for poor seaming).

3.3 A second batch size is then determined and the process is continued. Depending on the project size, i.e., the total length of seaming, a number of decision cycles can occur until the project is finished.

3.4 It is seen that the number of samples required for the entire project is either fewer than the start-up frequency (for good seaming); the same as the start-up frequency (for matching the initial anticipated failure percentage); or more than the start-up frequency (for poor seaming).

4. Significance and Use

4.1 Construction quality assurance (CQA) and construction quality control (CQC) organizations, as well as owner/operators and agency regulators can use this guide to vary the sampling interval of geomembrane seam samples (i.e., the taking of field samples for destructive shear and peel testing) from an initial, or start-up, interval. This initial interval is often 1 destructive seam sample in every 150 m (500 ft) of seam length.

4.2 The guide leads to increasing the sampling interval for good seaming practice (hence fewer destructive samples) and to decreasing the sampling interval for poor seaming practice (hence additional destructive samples).

4.3 Use of the guide should provide an incentive for geomembrane installers to upgrade the quality and performance of their field seaming activities. In so doing, the cutting of fewer destructive samples will lead to overall better quality of the entire liner project, since the patching of previously taken destructive samples is invariably of poorer quality than the original seam itself.

Note 3 - It is generally accepted that field patching of areas where destructive samples had been taken using extrusion fillet seaming is less desirable than the original seam which was made by hot wedge welding.

4.4 Control charts are illustrated in Appendix A which can be used by geomembrane installers and their construction quality control (CQC) personnel for improvement in overall job quality and identification of poorly performing seaming personnel and/or equipment.

5. Suggested Methodology

Using the concepts embodied in the method of attributes, the following procedure is based on adjustments to sequential sampling.

5.1 Typical Field Situation - In order to begin the process, a project-specific total seam length must be obtained from the installers panel (roll) layout plan. Also, an initial, or start-up, sampling interval must be decided upon. From this information the total number of samples that are required based on the start-up sampling interval can be obtained.

Example 1 - A given project has 54,000 m (180,000 ft) of field seaming. The start-up sampling frequency is 1 sample per 150 m (500 ft). Therefore, the total number of samples required if the start-up interval is kept constant will be:

$$\frac{54,000}{150} = 360\,\text{samples}$$

5.2 Determination of Initial Batch Size - Using the table shown below, the initial batch size from which to possibly modify the start-up sampling interval is obtained.

Table 1 - Batch Size Determination, after ANSI/ASQC Z1.4 [1993]

No. of Required Samples Based on Initial or Modified Sampling Interval	No. of Samples Needed (Batch Size) to Determine Subsequent Sampling Interval
2 - 8	2
9 - 15	3
16 - 25	5
26 - 50	8
51 - 90	13
91 - 150	20
151 - 280	32
281 - 500	50
501 - 1200	80
1201 - 3200	125

Example 1 (cont.) - For 360 samples, a batch size of 50 is necessary. As production seaming progresses, these 50 samples are tested (either as they are taken or in a batch) and the number of failures is determined.

5.3 Verification of Start-Up Sampling Interval - A sampling table is now used which separates the number of failures within this initial batch size into three categories: a relatively low number of failures (where the sampling interval can be increased), the anticipated number of failures (where the sampling interval is maintained), or a relatively high number of failures (where the sampling interval should be decreased). Table 2 provides this information which is based upon the operation characteristic (OC) curves of Appendix B.

Example 1 (cont.) - Assuming an anticipated failure percentage of 2% (recall Note - 2), Table 2 results in the three categories shown below:

- 0 or 1 failure out of 50; the sampling interval can be increased
- 2 or 3 failures out of 50; the sampling frequency should remain at 1 sample per 150 m (500 ft)
- 4 or more failures out of 50; the sampling interval should be decreased

Table 2 - Sampling Table Containing the Number of Failed Samples to be used for Interval Sampling Interval Modification, see Appendix B for details

No. of Required Samples Based on Initial or Modified Sampling Interval	No. of Samples Needed (Batch Size) to Determine Subsequent Sampling Interval	Anticipated Failure Percentage*							
		1%		2%		3%		4%	
		I	D	I	D	I	D	I	D
2 - 8	2	0	1	0	1	0	1	0	1
9 - 15	3	0	1	0	1	0	2	0	2
16 - 25	5	0	1	0	1	0	2	0	2
26 - 50	8	0	1	0	1	0	2	0	2
51 - 90	13	0	1	0	2	0	2	0	3
91 - 150	20	0	2	0	3	1	3	1	4
151 - 280	32	0	2	1	3	1	4	2	5
281 - 500	50	0	3	1	4	2	5	3	6
501 - 1200	80	1	4	2	6	3	7	5	9
1201 - 3200	125	2	5	4	7	5	9	7	11

No. of Required Samples Based on Initial or Modified Sampling Interval	No. of Samples Needed (Batch Size) to Determine Subsequent Sampling Interval	Anticipated Failure Percentage*							
		5%		6%		7%		8%	
		I	D	I	D	I	D	I	D
2 - 8	2	0	1	0	2	0	2	0	2
9 - 15	3	0	2	0	2	0	2	0	2
16 - 25	5	0	2	0	2	0	3	0	3
26 - 50	8	0	3	0	3	1	3	1	4
51 - 90	13	1	4	1	4	1	4	1	5
91 - 150	20	1	5	2	5	2	5	2	6
151 - 280	32	2	6	3	6	3	7	4	7
281 - 500	50	4	7	4	8	5	9	6	10
501 - 1200	80	6	10	7	11	8	12	9	14
1201 - 3200	125	9	13	10	15	12	17	13	19

No: *To be selected by CQA, owner or regulatory organizations

I = Increase the sampling interval if the number of failed samples found in the batch does not exceed the tabulated value.

D = Decrease the sampling interval if the number of failed samples found in the batch equals or exceeds the tabulated value.

5.4 Modification of Start-Up Sampling Interval - Depending upon the outcome of the previous section, the start-up sampling interval may be modified to a new value which will then require a new batch size to verify the modification. The process is then continued until the project is finished. Two examples will be provided using the above sampling table both with anticipated failure percentages of 2.0%: Example 2 illustrates good seaming, and Example 3 illustrates poor seaming.

Example 2 - Using the same project seam length and start-up sampling frequency as in the previous example assume that the start-up batch of 50 samples in the previous example had 2-failures. The decision is then to continue at a 1 destructive sample in 150 m (500 ft) sampling interval. Thus the second batch size from Table 1 is again 50 samples, see Table 3. Table 3(a) is in S.I. units and Table 3(b) is in English units. Now assume in the second batch there are no failures. This allows the sampling interval to be increased, e.g., to 1 sample in 180 m (600 ft). From Table 1, the third batch size is then decreased to 32 samples. The process is continued in this manner until the project is concluded. For this hypothetical situation Table 3(a) illustrates that 265 samples (or 266 samples when using the English units in Table 3(b)) are necessary. Note that by using a constant interval of 1 sample in 150 m (500 ft), 360 samples would have been necessary. Also note that the maximum sampling interval was fixed at 310 m (1000 ft).

Note 4 - This example, and the following one, use a changing sampling interval of ± 20% from the previous value. That is, when good seaming allows for an increase in sampling interval; the progression being from 150, 180, 215, 260 to 310 m (500, 600, 720, 850 to 1000 ft), respectively. A maximum interval of 310 m (1000 ft) is recommended, but clearly this value is at the discretion of the organizations involved. Conversely, poor seaming requires a decrease in sampling interval; the progression being from 150, 120, 100, 80 to 65 m (500, 400, 320, 250 to 200 ft), respectively. A minimum interval of 65 m (200 ft) is recommended, but clearly this decision is also at the discretion of the organizations involved

Table 3(a) - Results of Example 2 (**in S.I. Units**) Illustrating the Variation of the Sampling Interval Based on a 2.0% Anticipated Failure Percentage With a "Good" Quality Installer

Batch number	Sampling Interval (m)	No. of Remaining Samples Required	Batch size	Cumulative Distance (m)	Number of failures	Decision made
1	150	360	50	7500	2	Stay
2	150	310	50	15000	0	Increase
3	180	217	32	20760	0	Increase
4	215	155	32	27640	2	Stay
5	215	123	20	31940	1	Stay
6	215	103	20	36240	0	Increase
7	260	68	13	39620	1	Stay
8	260	55	13	43000	0	Increase
9	310	35	8	45480	0	Stay
10	310	27	8	47960	0	Stay
11	310	19	5	49510	0	Stay
12	310	14	3	50440	0	Stay
13	310	11	3	51370	0	Stay
14	310	8	2	51990	0	Stay
15	310	6	2	52610	0	Stay
16	310	4	2	53230	0	Stay
17	310	2	2	53850	0	Done

Total Number of tests per 54,000 m of seam project = 265

Table 3(b) - Results of Example 2 (**in English Units**) Illustrating the Variation of the Sampling Interval Based on a 2.0% Anticipated Failure Percentage With a "Good" Quality Installer

Batch number	Sampling Interval (m)	No. of Remaining Samples Required	Batch size	Cumulative Distance (m)	Number of failures	Decision made
1	500	360	50	25000	2	Stay
2	500	310	50	50000	0	Increase
3	600	217	32	69200	0	Increase
4	720	154	32	92240	2	Stay
5	720	122	20	106640	1	Stay
6	720	102	20	121040	0	Increase
7	850	69	13	132090	1	Stay
8	850	56	13	143140	0	Increase
9	1000	37	8	151140	0	Stay
10	1000	29	8	159140	0	Stay
11	1000	21	5	164140	0	Stay
12	1000	16	5	169140	0	Stay
13	1000	11	3	172140	0	Stay
14	1000	8	2	174140	0	Stay
15	1000	6	2	176140	0	Stay
16	1000	4	2	178140	0	Stay
17	1000	2	1	179140	0	Done

Total Number of tests per 180,000 ft of seam project = 266

Example 3 - Using the same project seam length and start-up sampling frequency as Example 1, assume that the start-up batch of 50 samples had 3- failures. The decision is then to continue at a 1 destructive sample in 150 m (500 ft) sampling interval. Thus the second batch size is again 50 samples as it was with Example 2, see Table 4. Table 4(a) is in S.I. units and Table 4(b) is in English units. Now assume in the second batch there are 2-failures. The decision is to again continue at a 1 destructive sample in 150 m (500 ft) sampling interval. From Table 1, the third batch size is then decreased to 32 samples. The process is continued in this manner until the project is concluded. For this hypothetical situation Table 4 illustrates that 412 samples are necessary. Note that by a constant interval of 1 sample in 150 m (500 ft), 360 samples would have been necessary. Furthermore, a good seamer (as illustrated in Example 2) would only have had to take 265 samples.

Table 4(a) - Results of Example 3 **(in S.I. Units)** Illustrating the Variation of the Sampling Interval Based on a 2.0% Anticipated Failure Percentage With a "Poor" Quality Installer

Batch number	Sampling Interval (m)	No. of Remaining Samples Required	Batch size	Cumulative Distance (m)	Number of failures	Decision made
1	150	360	50	7500	3	Stay
2	150	310	50	15000	2	Stay
3	150	260	32	19800	2	Stay
4	150	228	32	24600	3	Decrease
5	120	245	32	28440	3	Decrease
6	100	256	32	31640	1	Increase
7	120	186	32	35480	1	Increase
8	150	123	20	38480	2	Stay
9	150	103	20	41480	1	Stay
10	150	83	13	43430	2	Decrease
11	120	88	13	44990	2	Decrease
12	100	90	13	46290	1	Stay
13	100	77	13	47590	1	Stay
14	100	64	13	48890	1	Stay
15	100	51	13	50190	0	Increase
16	120	32	8	51150	1	Stay
17	120	24	5	51750	1	Decrease
18	100	23	5	52250	0	Increase
19	120	15	3	52610	0	Increase
20	150	9	2	52910	1	Decrease
21	120	9	2	53150	1	Decrease
22	100	11	3	53210	0	Increase
23	120	7	2	53390	0	Increase
24	150	5	2	53510	0	Increase
25	180	3	2	53750	0	Done

Total Number of tests per 54,000 m of seam project = 412

Table 4(b) - Results of Example 3 (**in English Units**) Illustrating the Variation of the Sampling Interval Based on a 2.0% Anticipated Failure Percentage With a "Poor" Quality Installer

Batch number	Sampling Interval (m)	No. of Remaining Samples Required	Batch size	Cumulative Distance (m)	Number of failures	Decision made
1	500	360	50	25000	3	Stay
2	500	310	50	50000	2	Stay
3	500	260	32	66000	2	Stay
4	500	228	32	82000	3	Decrease
5	400	245	32	94800	3	Decrease
6	320	266	32	105040	1	Increase
7	400	187	32	117840	1	Increase
8	500	124	20	127840	2	Stay
9	500	104	20	137840	1	Stay
10	500	84	13	144340	2	Decrease
11	400	89	13	149540	2	Decrease
12	320	95	13	153700	1	Stay
13	320	82	13	157860	1	Stay
14	320	69	13	162020	1	Stay
15	320	56	13	166180	0	Increase
16	400	35	8	169380	1	Stay
17	400	27	5	171380	1	Decrease
18	320	27	5	172980	0	Increase
19	400	18	3	174180	0	Increase
20	500	12	2	175180	1	Decrease
21	400	12	2	175980	1	Decrease
22	320	13	3	176140	0	Increase
23	400	10	2	176780	0	Increase
24	500	6	2	177140	0	Increase
25	600	5	2	177980	0	Done

Total Number of tests per 54,000 m of seam project = 412

5.5 Summary

This guide illustrates by means of hypothetical examples how a CQA and/or CQC organization can modify the sampling interval for taking destructive samples from a geomembrane seaming project. It is based on the method of attributes which is common to statistical control methods. The methodology uses sequential sampling to proceed from one decision to the next until the project is complete.

The result in using this guide for the above purpose is to reward good seaming performance by taking fewer destructive samples, and to penalize poor seaming performance by taking additional destructive samples. In the example illustrations, good seaming resulted in taking 265 samples (versus 360), or a decrease of 26% from the originally set constant interval of 1 sample per 150 m (500 ft). Conversely, poor seaming resulted in taking 412 samples (versus 360), or a 14% increase in the originally set constant interval of 1 sample per 150 m (500 ft.) of seam length.

GM 14 - Appendix A - General Principles of Control Charts

In order to control a production process, like the field seaming of geomembranes, it is necessary to identify and quantify characteristics which reflect the quality of the product. Such quality characteristics can be either discrete or continuous variables. For example, the number of pin holes in a sheet of geomembrane is a discrete variable. Variation in the thickness of a sheet of geomembrane, however, is considered to be a continuous variable.

Whether quality characteristics are discrete or continuous, variability in the observed values is unavoidable. In the theory of control charts, this variation is considered due to either random (common) or assignable (special) causes, Wadsworth (1989) and Deming (1982). Random causes are generally smaller, uncontrollable influences which cannot be removed from the process without fundamental changes in the process itself. An assignable cause, however, is an influence considered to be significant, unusual, and capable of being removed form the process. Such causes may be due to human error, variation in raw materials, or the need for machine adjustment.

An important tool used to reduce process variation is the use of control charts. When using control charts, control limits are used to determine whether the variability of the statistic over time appears to be due to random variation only, or if an assignable cause is present. In other words, the purpose of control charts is to establish a "statistical control" of the assignable causes of variation within of a process.

The control chart generally used to monitor conforming or non-conforming data, called attributes, is the *p*-chart, where "*p*" stands for the proportion of non-conforming items in the entire population. In the case of inspecting the quality of the seams of field deployed geomembranes, the *p*-value would be the historic failure percentage of the installer.

Suppose we have m subgroups (e.g., m different operators, or m different welding machines, or m working days, etc.) of varying sample sizes $n_1, n_2, ..., n_m$. The number of non-conforming (failed) samples in the ith subgroup is D_i, $i = 1, 2, ..., m$, so the proportion of non-conforming items (failure rate) in the ith subgroup is as follows:

$$\hat{p}_i = \frac{D_i}{n_i}, i = 1,2...,m \tag{A1}$$

For the *p*-chart, the values of $\hat{p}_i$ are plotted against the subgroup number with a control limit, *CL*, set at the following:

$$CL = p + 3\left[\frac{p(1-p)}{\bar{n}}\right]^{1/2} \tag{A2}$$

where $\bar{n} = \frac{1}{m}\sum_{i=1}^{m} n_i$ = average sample size.

Two examples follow:

Example A1 - Assume that a seaming project is expected to take 25-days for completion, i.e., m=25. The installer has a historic data indicating that the company's average failure percentage is 2.0%. As the work progresses, the number of destructive seam samples and the respective numbers of failures are listed in tabular form as shown in the following table. Note that the daily failure rates, i.e., $\hat{p}_i$, are also shown in the table. The control chart of this project can now be developed.

Subgroup No. (days)	No. of destructive samples	No. of failures in subgroup	Failure Percentage $\hat{p}$
1	12	0	0.000
2	14	0	0.000
3	9	0	0.000
4	7	0	0.000
5	13	1	0.077
6	15	0	0.000
7	19	1	0.053
8	13	0	0.000
9	14	1	0.071
10	9	0	0.000
11	17	1	0.059
12	16	0	0.000
13	7	0	0.000
14	22	1	0.045
15	18	0	0.000
16	16	0	0.000
17	15	0	0.000
18	16	0	0.000
19	14	0	0.000
20	16	0	0.000
21	22	1	0.045
22	18	0	0.000
23	16	0	0.000
24	9	0	0.000
25	13	1	0.077

Solution: From Equation (B2), the control limit is calculated as follows:

$$CL = 0.02 + 3\left[\frac{0.02(1-0.02)}{360/25}\right]^{1/2} = 0.13$$

The control chart can now be obtained by plotting the subgroup failure rate against the subgroup number (i.e., days) along with the control limit, CL = 0.13. The results are shown in the following figure, note that the 2.0% historic failure rate is also shown.

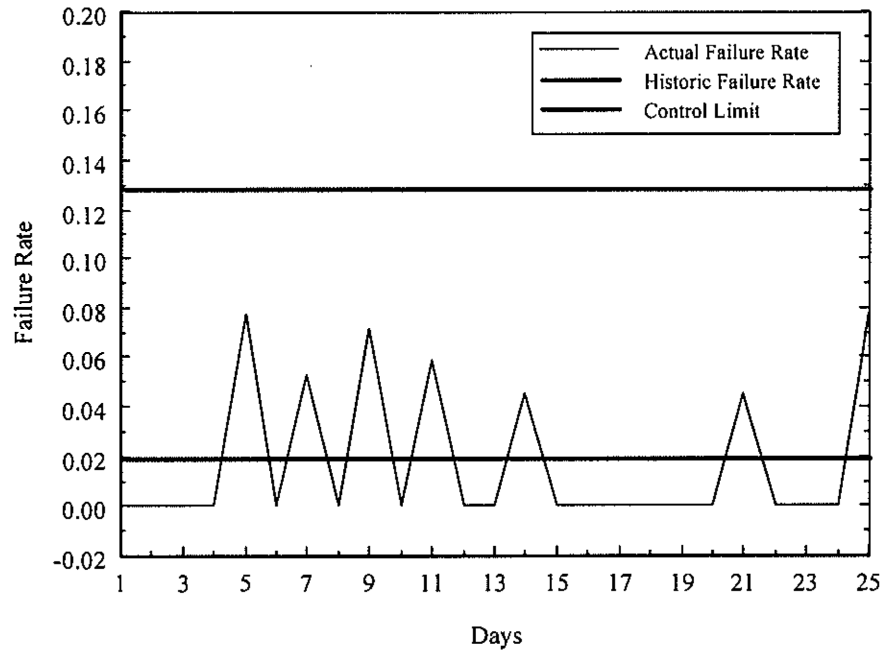

Figure A1 - The Resulted Control Chart of Example A-1.

As seen in the above control chart, the entire 25-day record of the failure rate of this project falls below the control limit set on the basis of the installer's 2.0% historic failure rate. That is to say, the variations in the daily failure record were due to random causes only and no assignable cause was identified. The above control chart indicates that no corrective action is necessary. This is an example of good seaming control.

Example A2 - For a similar size seaming project and historic record (i.e., 2% failure rate) as presented in Example A-1, a second installer has a poorer destructive seam record as shown in the following table. The control chart of this particular situation can also be developed.

Subgroup No. (days)	No. of destructive samples	No. of failures in subgroup	Failure Percentage $\hat{p}$
1	12	1	0.083
2	14	0	0.000
3	9	1	0.111
4	7	0	0.000
5	13	1	0.077
6	15	1	0.067
7	19	3	0.158
8	13	2	0.154
9	14	1	0.071
10	9	0	0.000
11	17	0	0.000
12	16	1	0.063
13	7	1	0.143
14	22	2	0.091
15	18	1	0.056
16	16	2	0.125
17	15	0	0.000
18	16	1	0.063
19	14	0	0.000
20	16	1	0.063
21	22	2	0.091
22	18	1	0.056
23	16	3	0.188
24	9	0	0.000
25	13	1	0.077

Solution: Since the historic failure rate is the same as shown in Example A-1.A new control chart can now be obtained by plotting the subgroup failure rate against the subgroup number (i.e., days) along with the control limit, CL = 0.13. The results are shown in the following figure. Again, the 2.0% historic failure rate is also shown.

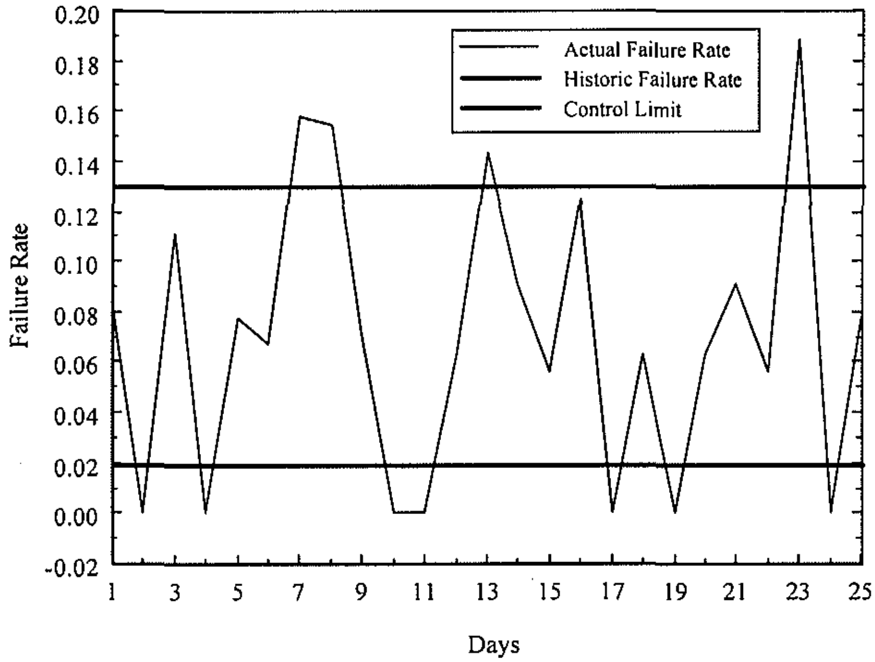

Figure A2 - The Resulted Control Chart of Example A-2.

As seen in the above control chart, the daily failure rates at day 7, 8, 13 and 23 exceed the control limit set on the basis of the installer's 2.0% historic failure rate. That is to say, there are possible assignable causes on those days. From the stand point of construction quality control, the installer should check the record on those days, identify the cause(s) of such variations, and take necessary corrective actions. This is an example of poor seaming.

GM 14 - Appendix B - The Selection of the "I" and "D" Values

In this appendix, the procedure used for selecting the "I" and "D" values listed in Table 2 is presented. The required background, e.g., the concept of sampling risk and the operating characteristics (OC) curves, are briefly discussed.

Sampling Risk

Sampling involves a degree of risk that the actual samples do not adequately reflect the conditions of the lot. For example, when using the sampling plan recommended in this guide, there are two common risks [see Juran and Gryna (1980)[1] and Juran el. al (1974)[2] for details]:

1. A good seaming practice might be penalized. This is generally referred as the installer's risk and denoted as the α risk.
2. A poor seaming practice might go undetected. This is generally referred as an owner/regulators risk and denoted as the β risk.

The effects (impacts) of the relative degree of these two risks are summarized in Table B1.

Table B1 - The Effects of the Relative Degree of α and β Risks.

Relative Degree	Types of Risks	
	Installers (α) Risk	Owner/Regulators (β) Risk
Low	Loose CQA control; low testing cost	Tight CQA control; high testing cost
High	Tight CQA control; high testing cost	Loose CQA control; low testing cost

Operating Characteristics (OC) Curves

Both of the risks can be quantified by sampling-plan-specific *operating characteristics* (OC) *curves*. The OC curve for a sampling plan is a graph whichs plots the probability that the sampling plan will accept a lot (i.e., the P_a value) versus the percent defective samples in that particular lot. Note that the term "sampling plan" used here corresponds to a batch of "*n*" destructive testing samples and the criteria for adjusting the sampling interval. Recall Table 2 in the main body of this guide. Figure B1 illustrates the concept of OC curves. In Figure B1, the dashed curve represents an "ideal" OC curve. Here it is desired to accept all lots having less or equal than 2% and reject all lots having greater than 2% failures. In reality, all sampling plans have risks that a "good" lot will be rejected or a "bad" lot will be accepted. This is illustrated by the solid S-shaped curve shown in Figure B1. It is seen that this particular sampling plan will

[1] Juran, J. M, and Gryna, M, (1980), Quality Planning and Analysis, 2nd. ed., McGraw-Hill Book Company, New York.

[2] Juran, J. M, Gryna, M, and Bingham, R. S., ed., (1974), Quality Control Handbook, 3rd. ed., McGraw-Hill Book Company, New York.

have a 5% risk (100% - 95%) of rejecting a lot having only 1% defects (i.e., a "good" lot) and a 10% risk of accepting a lot having 5% defects (i.e., a "bad" lot).

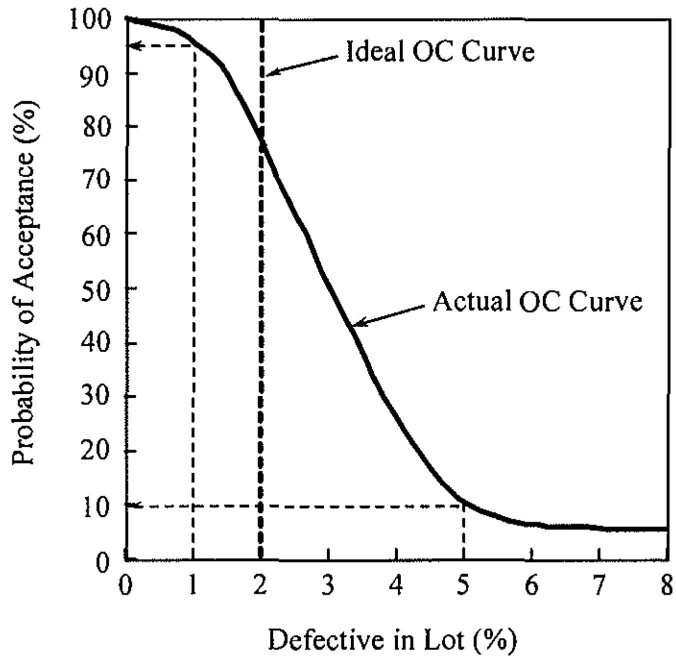

Figure B1 - Ideal and Actual Operating Characteristics Curves for a Sampling Plan

An OC curve can be developed by determining the probability of acceptance for several values of the percent defects. To do so, a statistical distribution of the acceptance probability has to be assumed first. There are three distributions which can be used: hypergeometric, binomial and Poisson distribution[3]. The Poisson distribution is generally preferable due to the ease of calculation. It is used in this guide. The Poisson distribution function to be applied to an acceptance sampling plan is as follows:

$$P\begin{pmatrix}\text{exactly "c" defects} \\ \text{in a batch of size "n"}\end{pmatrix} = \frac{e^{-np}(np)^c}{c!} \qquad \text{(B1)}$$

Most statistics books provide Poisson distribution tables which give the probability of "c" or less defects in a batch of size "n" from a lot having a fraction of defect "p".

<u>The Selection of the "I" and "D" Values Listed in Table 2</u>

As mentioned earlier, each of the sampling plans recommended in this guide consists of three variables: the batch size "n", the values of "I" and "D". Note that the values of "I" and "D" are specific values of "c" mentioned in Equation B1. The "I" value corresponds to the judgment

[3] Grant, E. L. (1972), <u>Statistical Quality Control</u>, 4th. ed., McGraw-Hill Book Company, New York.

criterion of rewarding good seaming practice, i.e., increasing the sampling interval if the number of failed samples does not exceed this particular value. The "D" value, on the other hand, corresponds to the judgment criterion of penalizing poor seaming practice, i.e., decreasing the sampling interval if the number of failed samples equals or exceeds this particular value.

The concept of the OC curves is used to determine the actual values of I's and D's for different sampling plans. The criteria used are as follows:

- For a batch of size "n", the "I" value should yield a 80~90% probability of rewarding good seaming practice, i.e., $80\% < P_a < 90\%$.
- For a batch of size "n", the "D" value should yield a risk of 0.5% or less of penalizing good seaming practice, i.e., $P_a \geq 99.5\%$. In other words, the probability for good seaming practice to be penalized is extremely small, i.e., less than 0.5%.

The above criteria is subjective. Nevertheless, it is felt to be adequate since the rights of both the installer and the owner/regulator are protected. Recognize that a sampling plan with tighter control (i.e., smaller values of "I" and "D") might seem to be more ideal at first glance, but it may result in a significant increase in the required number of destructive tests, i.e., it may be counter productive.

As an illustration, Figure B2 shows the graphic procedure of obtaining the "I" and "D" values for a batch of 50 samples (n=50) and an anticipated failure percentage of 4%. [In other words, it illustrates the procedure of obtaining one particular pair of numbers listed in Table 2, namely, "I" and "D" equal to 3 and 6, respectively.] Note that each OC curve shown in Figure B2 corresponds to a specific "c" value and is obtained via a Poisson distribution table.

Figure B2 can also used to determine the values of "I" and "D" for sampling plans with the same batch size (i.e., n = 50) but different anticipated failure percentage. The rest of the values listed in Table 2 can be verified in a similar manner using OC curves corresponding to different batch sizes.

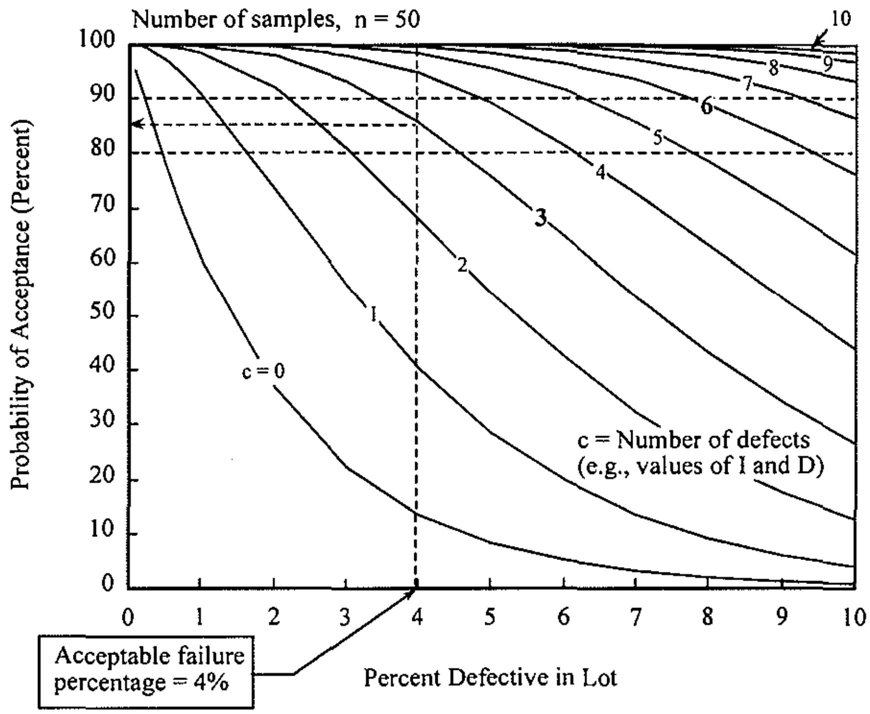

Figure B2 - The Determination of the Values of "I" and "D" for a Batch with 50 Samples and an Anticipated Failure Percentage of 4.0%.

SECTION 02712
DRAINAGE GEOCOMPOSITE

PART 1 GENERAL DESCRIPTION:

1.1 GENERAL

A. The Contractor shall furnish all labor, material, and equipment to complete installation of the DRAINAGE GEOCOMPOSITE (DGC), including all necessary and incidental items, in accordance with the Drawings and these Specifications.

1. RELATED SECTIONS

A. Section 02561, Cover System Performance Testing

B. Section 02565, Geosynthetics

C. Section 02597, Geomembrane

1.3. REFERENCES

A. The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these specifications.

B. GRI-GC8, Standard Guide for Determination of the Allowable Flow Rate of a Drainage Geocomposite

C. ASTM D4716, Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using Constant Head.

D. ASTM D 1238, Standard Test Method for Flow Rates of Thermoplastics by Extrusion Process Plastometer.

E. ASTM D 1505 Standard Test Method for Density of Plastics by the Density-Gradient Technique.

F. ASTM D 1621, Standard Test Method for Compressive Properties of Rigid Cellular Plastics.

G. ASTM D 4218, Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle Furnace Technique

H. ASTM D 4491, Standard Test Method for Water Permeability of Geotextiles by the Permitivity Method.

I. ASTM D 4533, Standard Test Method for Trapezoid Tearing Strength of Geotextiles.

J. ASTM D 4595, Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method.

K. ASTM D 4632, Standard Test Method for Breaking Load and Elongation of Geotextiles (Grab Method).

L. ASTM D 4751, Standard Test Method for Determining Apparent Opening Size of a Geotextile.

M. ASTM D4833, Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.

N. ASTM D 5199, Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.

O. ASTM D 7005, Standard Test Methods for Determining the Bond Strength (Ply Adhesion) of Geocomposites

P. ASTM G154, Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials

1.4. QUALITY ASSURANCE

2. Quality Assurance during installation of DGC will be provided by the Engineer as described in the Project CQA Plan.

PART 2 PRODUCTS:

2.1 MATERIALS

A. The polymer used to manufacture the Geonet core of the DGC shall be polyethylene. Manufacturer shall certify that no regrind material is used in the geonet manufacturing process.

B. The drainage core of the DGC shall be manufactured by extruding polyethylene to form a triaxial void maintaining structure. The geonet shall meet the property requirements listed in Table 1.

C. The geotextile of the DGC shall be UV resistant, continuous filament, needle punched, nonwoven polypropylene geotextile. The geotextile shall meet the property requirements listed in Table 2.

D. Labels on each roll of DGC shall identify the length, width, lot and roll numbers, and name of Manufacturer.

E. If requested by the Engineer, the manufacturer of the DGC shall submit documents for the Engineer's review that the DGC to be supplied to the project site has proven installation. As a minimum, the manufacturer shall certify that:

1. The proposed DGC has been installed at least (to be determined by the Engineer) million square feet. The proposed DGC has been installed at least 10 projects that are in operations for a minimum two years.

2. The proposed DGC has been installed at least 5 superfund projects.

3. It has not supplied any drainage product that has been documented to be contributing towards a catastrophic system failure.

TABLE 1: REQUIRED DRAINAGE GEOCOMPOSITE PROPERTIES

PROPERTY	TEST METHOD	UNITS	VALUES
Geonet			
Structure	Triaxial		
Thickness (min.)	ASTM D 5199	mil	340
Tensile Strength (min.)	ASTM D 4595	lb/ ft	425
Density (min.)	ASTM D 1505	g/cm^3	0.94
Melt Flow Index (max.)	ASTM D 1238	g/10 min	1.0
Carbon Black Content (min.)	ASTM D 4218	%	2
Creep Reduction Factor[1]	GRI- GC8	-	1.1
Geocomposite			
Ply Adhesion (min.)	ASTM D7005	lb/inch	0.5
Transmissivity[2] –Machine Direction (min.)	ASTM D 4716 GRI –GC8	(m^2/sec)	see Section 02561, Part 3, 3.2E

Notes:

1. The creep reduction factor is determined from 10,000 hour test duration, extrapolated to 30 years and using a compressive load of 1,000 psf.

2. If requested by the Engineer, transmissivity tests may be conducted at the frequency of 200,000 square feet per test. The transmissivity to be determined shall be the appropriate manufacturer's stated transmissivity for the following testing scenario. The normal compressive load shall be 1,000 psf at hydraulic gradients of 0.1 and 0.33. Testing boundary conditions from the top to bottom are: upper steel load plate/Ottawa sand/Geocomposite/Geomembrane/lower load plate (the flat side of the geocomposite facing the soil boundary), with a minimum seating period of 100 hours.

TABLE 2: REQUIRED GEOTEXTILE PROPERTIES

PROPERTY	TEST METHOD	UNITS	VALUE
Serviceability Class	Class 2		
UV Resistance @500 Hours (MIN)	ASTM G 154 or D 4355	%	70
Grab Tensile Strength (MARV)	ASTM D4632	lbs	160
Grab Elongation (MARV)	ASTM D4632	%	50
Trapezoid Tear (MARV)	ASTM D4533	lbs	80
Puncture Strength (MARV)	ASTM D4833	lbs	110
AOS (MaxARV)	ASTM D4751	US Sieve	80
Permittivity (MARV)	ASTM D4491 Falling head	sec^{-1}	1.1

2.2. SUBMITTALS

A. The Contractor shall submit the following to the Engineer:

1. The Contractor shall submit one copy of a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the DGC attesting that the DGC meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample (12" x 12") of the DGC to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.

2. The Contractor's plan for shipping, handling, and storage shall be submitted for review.

3. The Contractor shall submit and have approved by the engineer a DGC panel layout prior to placement of the DGC. The predominant flow direction of the DGC is in the machine (roll) direction. The DGC shall be installed to maximize its flow capability.

4. For DGC delivered to the site, quality control certificates, signed by the Manufacturer’s quality manager shall be provided for every roll of DGC. Each certification shall have the roll identification number(s), test methods, frequency, and test results. At a minimum, the test results and frequency of testing shall be as shown in Table 4 of this section.

3. Furnish copies of delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

TABLE 3: REQUIRED MANUFACTURER'S QUALITY CONTROL TEST DATA

PROPERTY	TEST METHOD	UNITS	FREQUENCY
Resin Tests			
DENSITY	ASTM D1505	g/cm^3	Per Lot
MELT FLOW INDEX	ASTM D1238	g/10 min	Per Lot
Geonet Tests			
THICKNESS	ASTM D5199	mm	50,000 ft^2
CARBON BLACK CONTENT	ASTM D4218	%	50,000 ft^2
TENSILE STRENGTH-MD	ASTM D4595	lbs/ft	50,000 ft^2
Geotextile Tests			
WEIGHT	ASTM D3776	Oz/sy	100,000 ft^2
AOS	ASTM D4751	US Sieve (mm)	500,000 ft^2
PERMITTVITY	ASTM D4491 Falling head	sec^{-1}	500,000 ft^2
GRAB TENSILE STRENGTH	ASTM D4632	lbs	100,000 ft^2
TRAPEZOID TEAR	ASTM D4533	lbs	100,000 ft^2
PUNCTURE STRENGTH	ASTM D4833	lbs	100,000 ft^2
Geocomposite Tests			
PLY ADHESION	ASTM D7005	lbs/in	100,000 ft^2
TRANSMISSIVITY-MD	ASTM D4716	m^2/sec	200,000 ft^2

PART 3 EXECUTION:

3.1 CONSTRUCTION

A. Handling and Placement

1. After the substratum/geomembrane has been installed/ constructed, tested and approved by the Engineer, the surface shall be cleaned and free of excess dirt and debris.

2. The Contractor and the Installer shall handle all geocomposite in such a manner as to ensure it is not damaged in any way. Precautions shall also been taken to prevent damage to underlying layers during placement of the geocomposite.

3. The geocomposite roll should be installed in the direction of the slope, following the labeled instructions as provided by the manufacturer with respect to the top/bottom sides.

4. If the project contains long, steep slopes, special care shall be taken so that only full-length rolls are used at the top of the slope.

5. In the presence of wind, all geocomposite shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during placement and shall remain until replaced with cover material.

6. If necessary, the geocomposite shall be positioned by hand after being unrolled to minimize wrinkles.

7. If the project includes an anchor trench at the top of the slope, the geocomposite shall be properly anchored to resist sliding. Anchor trench compacting equipment shall not come into direct contact with the geocomposite.

8. If there are any obstructions (such as outlet pipes or monitoring wells) while deploying the geocomposite, the geocomposite shall be cut to fit around the obstruction. Care shall be taken as to make sure there is no gap between the obstruction and the geocomposite. The geocomposite shall be cut in a way that the lower geotextile and geonet core is in contact with the obstruction and the upper geotextile has an excess overhang. There must be enough of the upper geotextile to be able to tuck the upper geotextile back under the geocomposite to protect the exposed geonet core, and prevent soil particles from migrating into the geonet core flow channels.

B. Seams and Overlaps

1. Each component of the geocomposite (geotextile(s) and geonet) shall be secured or seamed to the like component at overlaps.

2. Geonet Component

4. Adjacent edges of geonet along the length of the geocomposite, shall be overlapped 2-3 inches, as seen Figure 1. These overlaps shall be joined by tying the geonet cores together with white or yellow cable ties or plastic fasteners. These ties shall be spaced at a maximum of every 5 feet along the roll length, or a maximum of 2 feet if the geocomposite is installed vertically.

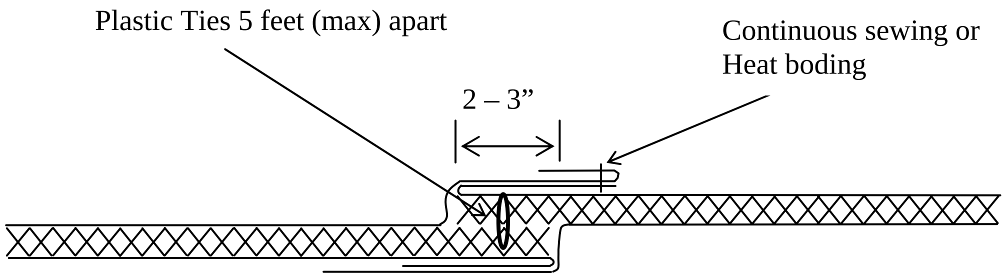

Figure 1: **Overlap Along Roll Length ((MD)**

5. Adjoining geocomposite rolls (end to end) along the roll width shall be shingled down in the direction of the slope, with the geonet portion of the top geocomposite overlapping the geonet portion of the bottom geocomposite a minimum of 12 inches across the roll width, see Figure 2. Geonet shall be tied every 12 inches across the roll width and every 6 inches in the anchor trench or as specified by the Engineer.

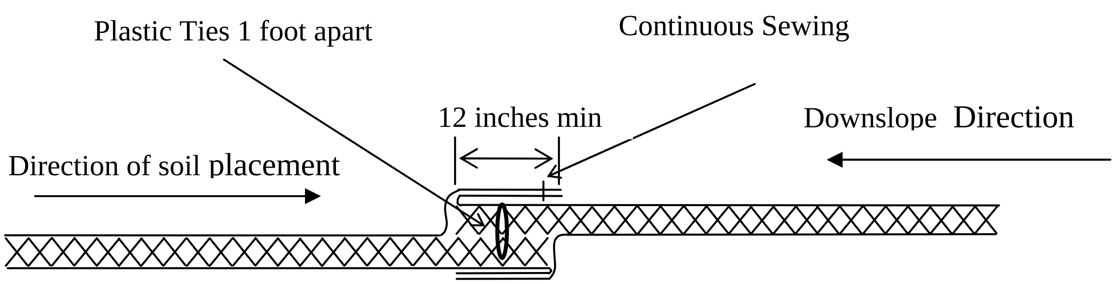

Figure 2: **Overlap Along Roll Width (CD)**

3. Geotextile Component

   a. The bottom layer of geotextile (if any) shall be overlapped.

   b. The top layers of geotextile shall be sewn together, or at the discretion of the Engineer may be heat bonded or wedge welded.

Geotextiles shall be overlapped a minimum of 4 inches prior to seaming or heat bonding. The seam shall be a two-thread, double-lock stitch, or a double row of single-thread, chain stitch. If heat bonding is to be used, care must be taken to avoid burn through of the geotextile. It is important that the geotextiles be joined continuously along to the roll as to prevent any fugitive particle migration into the geonet core flow channels.

C. Repair

1. Any small holes or tears in the top geotextile shall be patched with an 8" x 8" geotextile piece. The patching geotextile shall be the same as the original one. Apply the spray adhesive (*3M Super 77 adhesive is the recommended)* to one side of the 8" x 8"textile patch. Center and apply the 8" x 8" textile patch over the blemish, hole, tear or thin spot in the geotextile. Firmly press 8" x 8" textile patch over the repair area. If the damaged area of the geotextile is greater than this standard patch size, a bigger size patch is recommended using a multitude of 8" x 8" patches. If the geotextile is damaged beyond 50 percent of the width of the roll, a continuous piece of fabric the same width as the geocomposite may be cap-stripped directly to the adjacent seams by sewing a portion of the new geotextile in place.

2. Any large rips, tears or damage areas on the deployed geocomposite core shall be removed and patched by placing a patch extending 12" beyond the edges of the damaged areas. The patch shall be secured to the original geonet tying every 6 inches with approved tying devices. If the hole or tear width across the roll is more than 50% percent the width of the roll, the damaged area shall be cut out.

D. Cover Soil Placement

1. Placement of the cover soil is recommended to proceed immediately following placement and inspection of the geocomposite.

2. In applying fill material, no equipment shall drive directly across geocomposite. Acceleration or deceleration shall be in a smooth and gentle manner. Operator shall not make any sudden turns or stops when driving on the geonet or geocomposite. If any tear or local damage occurs to the geotextile, geonet or geocomposite, patching technique as described in the above section shall be used.

6. The full thickness of the vegetative support layer shall be placed and spread utilizing vehicles with a low ground pressure (LGP). The cover soil shall be placed on the geocomposite from the bottom of the slope proceeding upwards and in a manner, which prevents instability of the cover soil or damage to the geocomposite.

END OF SECTION 02712

PART 1 – GENERAL:

1.1 WORK INCLUDES

A. Revegetating all areas disturbed by construction and supplying slope and erosion control to unprotected slopes.

1.2 RELATED SECTIONS

A. Section 02200 Earthwork

A. SUBMITTALS

The Contractor shall submit the following items to the Engineer at least twenty (20) calendar days prior to delivery to the Site:

A. Final mix design and agronomic test results of topsoil(s). Include organic content, pH, and N-P-K results.

B. Description of grass seed mixtures, fertilizer, mulch, and lime and the names of material suppliers for each product.

C. Description of seeding, fertilizing, adding lime and mulching equipment and proposed revegetation procedures.

B. DELIVERY, STORAGE, AND HANDLING

A. Deliver seed mixtures in sealed bags, individually marked for content. Comply with seed supplier recommendations for storage. Mix seed on-site, immediately before application.

B. Deliver fertilizers in bulk quantities with appropriate shipping tags, chemical analysis, and name of manufacturer or product origin. Comply with manufacturer recommendations for storage and handling.

C. Deliver mulch and tackifier in manufacturer-sealed containers. Comply with manufacturer recommendations for site storage, dilution, mixing, and application.

D. Maintain delivered stocks in cool, dry, covered and protected location prior to site mixing and application. Replace any seed damaged during storage.

PART 2 – PRODUCTS:

2.1 SEED MIXTURE

A. Provided certified seed consignments in accordance with the specifications for Vermont approved CONSERVATION MIX seed mixture. The seed mixture shall be packed and labeled in accordance with industry standards as to seed purity and germination.

2.2 OTHER PRODUCTS

A. Topsoil: Native organic or organic amended materials from approved on-site or off-site borrow source meeting the requirements of Specifications 02200, Part 2, Section 2.6.

B. Hydraulic Applied Mulch: Cellulose fiber mulch such as Silvar Fiber or Engineer approved equivalent.

C. Tackifier: M-binder, Verdyol alginate, Plantago gum or Engineer approved equivalent non-asphalt tackifier.

D. Water: Water used in hydraulic applications shall be clean, fresh and free of substances, which could inhibit vigorous plant growth. The source of the water shall be approved by the Engineer prior to its use. Water from the Site shall <u>not</u> be used.

E. Blown Mulching Material: Grass hay or straw mulch shall be free from noxious weeds, mold or other objectionable material. The straw mulch shall contain at least 50 percent by weight material that is six (6) inches or longer.

F. Hydro Application: Wood or cellulose fiber product or Engineer approved equivalent specifically designed for use as a hydro-mechanical applied mulch. Acceptable Product: Conwed Hydro Mulch, Conwed Fibers, 231 4th Street SW, Hickory, NC; or EZ Spray 50/50 Blend, Phoenix Paper Products, RT 251, Lostant, IL 61334.

G. Mechanically-Bonded Fiber Matrix: The Mechanically-Bonded Fiber Matrix (M-BFM) shall be Conwed Fibers 3000 M-BFM, as manufactured by PROFILE Products or Engineer approved equivalent. The M-BFM shall require no cure time and be comprised of wood fiber, cross-linking hydrocolloid tackifier, co-polymer gel, and crimped interlocking fibers. The M-BFM shall demonstrate the following physical properties:

Property	Typical Requirements
Moisture Content	12% (± 3%)
Wood Fiber	85% max.
Locking Fibers	5% (± 1%)
Cross-linked Tackifier	10% (± 1%)
Water Holding Capacity	1500% min.
Organic Material	95% min.
Ash Content	5% (± 1%)
pH	4.8 (± 2)
Color	Green

H. Fertilizer: Provided in the following quantities and quality as determined by the agronomic testing:

1. Nitrogen, phosphate, and potassium shall be compound fertilizer.
2. Potassium shall be in the form of K_2O.
3. Phosphate shall be in the form of P_2O_5.

I. Wood Chips: Relatively fresh, undecayed, mechanically chipped on-site or off-site wood, substantially free of soil, tailing, waste rock, or other deleterious material.

PART 3 – EXECUTION:

3.1 TOPSOIL PLACEMENT

A. Place soil in one lift to the lines, grades, slopes, and thickness as shown on the Drawings.

C. PREPARATION OF SURFACES

A. Remove debris such as large stones and other obstructions that would interfere with normal seeding operations.

B. The plant growth substrate shall be lightly compacted with a track machine (bulldozer) or similar implement to provide a firm seed bed. The track machine shall operate up and down the slope to create cross-slope track "bars".

C. The seedbed shall be weed-free and use of herbicides will not be allowed.

D. After weed elimination, the seedbed shall be scarified/tilled to a depth of at least 6 inches, fertilized if not hydro-seeded and firmed. Areas not suitable for scarifying/tilling shall be left in a rough condition.

E. In areas where equipment cannot be operated, the seedbed shall be prepared by hand.

F. If the seedbed has become compacted, loosen and smooth the soil surface either after or in conjunction with fertilization if not hydro-seeded.

G. If the topsoil is too loose, compact to provide a firm seedbed.

3.3 FERTILIZER

A. If broadcast, apply fertilizer uniformly and rake to a 2-inch depth or apply mechanically to a depth of 2 inches. Apply just prior to seeding. Application rate shall be as determined by agronomic testing. The results of the testing shall be reviewed and approved by the Engineer.

B. Apply fertilizer with the mulch for hydro-seeding applications.

C. When applying materials by hydro-seeding, fertilizer shall be applied with the mulch.

3.4 SEEDING – GENERAL

D. Conduct seeding no later than September 15 unless approved by the Engineer. If seeding is not completed by September 15 other additional temporary erosion control measures such as erosion control mats will be required. Contractor and Engineer will coordinate a revised erosion control plan until seeding is completed in the following spring.

E. The method of seed application shall be hydraulic application including M-BFM or as otherwise approved by the Engineer. Seed application rates are seed rate X/acre for this method.

3.5 LIME

A. Application rate shall be as determined by agronomic testing.

B. Apply lime such that it is uniformly distributed.

3.6 HYDRO-SEED/MULCH

A. Materials shall be applied by a contractor experienced in the hydraulic applications with equipment of adequate volumetric capacity to complete the job in a timely fashion.

B. Use hydraulic equipment and application method of the slurry mixture acceptable to the Engineer.

C. Use commercial mulch tackifier approved by the Engineer. Handle and mix in accordance with manufacturer's recommendations.

3.7 MECHANICALLY-BONDED FIBER MATRIX

A. Apply the M-BFM, seed, and fertilizer in a manner approved by the Engineer.

B. Apply M-BFM for erosion protection at a rate of 3,000 pound/acre.

C. Spray M-BFM in a manner that ensures proper soil surface coverage.

D. Apply M-BFM to surfaces as part of the seeding process in two stages:

1. Apply first coat of 1,500 pound/acre mulch with seed mixture.
2. Apply second coat of 1,500 pound/acre mulch, fertilizer with tackifier.

3.8 WOOD CHIPS

A. Place wood chips in a manner which minimizes compaction.

B. Place wood chips 6 inches thick unless otherwise directed by the Engineer.

3.9 PROTECTION AND MAINTENANCE

A. Immediately re-seed areas which show bare spots prior to demobilization using appropriate erosion control techniques (i.e. mulch, M-BFM, etc.).

B. Protect seeded areas against traffic or other uses.

C. Maintain all seeded areas in good condition until satisfactory uniform growth is established. Maintenance may include watering, re-seeding, and re-fertilizing.

D. Satisfactory uniform growth will be defined as follows:

1. No bare spots larger than 3 square feet.
2. No more than 10 percent of any continuous area with bare spots exceeding 0.5 square feet.
3. No weed growth covering areas greater than one square foot.

E. All seeded areas shall be guaranteed by the Contractor for not less than one full year from time of final completion.

END OF SECTION 02900